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THE GEOLOGY AND PALEONTOLOGY OF THE MARINE PLIOCENE OF SAN DIEGO, CALIFORNIA

PART 1, GEOLOGY

BY

LEO GEORGE HERTLEIN
California Academy of Sciences

AND

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THE GEOLOGY AND PALEONTOLOGY OF THE MARINE PLIOCENE OF SAN DIEGO, CALIFORNIA

BY

LEO GEORGE HERTLEIN AND U. S. GRANT, IV

PART 1, GEOLOGY

INTRODUCTION

The chief object of this memoir is to describe and illustrate the marine Pliocene invertebrate fauna of the environs of San Diego,[1] California. The present paper contains a geological introduction consisting of a review of the literature and a brief account, largely descriptive, of the general geological and physiographic features present in the region from which the fossils were obtained, including also some of the contiguous area north and east. No attempt has been made to prepare an exhaustive report on the geology and physiography of the region, but it is hoped enough has been given to form a geologic setting for the stratigraphic study and for a comprehension of some of the conditions which effected the deposition of the Pliocene sediments and the distribution and occurrence of the species enumerated later on.

The field work upon which the geologic and stratigraphic portions are based, and which has resulted in the accumulation of large collections of fossils, was begun in 1926 when the region was visited by Eric Knight Jordan and Hertlein. Some collections were made and notes taken but the work had hardly begun when it was interrupted by the lamentable death of Mr. Jordan. The present authors resumed field work in 1927 and 1928, and both of them, or one or the other, have made several later trips, particularly in 1937, to supplement the collections or obtain new information on the geology and stratigraphy. The laboratory work was done largely at the University of California at Los Angeles and at the California Academy of Sciences, although occasionally certain investigations were carried out at Stanford University, the University of California at Berkeley, and at the Museum of the San Diego Society of Natural History. The somewhat belated appearance of this paper is due in large part to the preoccupation of both authors with their other duties, the work having been done during such spare time as only occasionally became available.

It was originally planned to have the complete memoir issued at one time, but the limited and somewhat indefinite periods during which both the authors could devote their entire attention to bringing the manuscript up to date, and later reading the proofs, made its separation into parts necessary. The present part containing only the geological and general introductory matter will be followed by the several parts containing the systematic paleontology and it is proposed, in a final part, to include a discussion of the age and significance of the fauna as a whole and its correlation with that of other marine Pliocene formations in western North America.

Without the assistance of a number of persons this report could not have been prepared in its present form, and this occasion is taken to offer grateful acknowledgment of assistance received from them. Later special acknowledgment will be made of assistance received while working on the paleontologic parts. The late Mr. Frank Stephens, veteran naturalist of San Diego and former Curator Emeritus of the Museum of the San Diego Society of Natural History, was of great assistance to us during the field work. He accompanied us during the beginning of the field work and saved us much time in pointing out important fossil localities, some of which would have been difficult to discover or might have been overlooked entirely. Mrs. Kate Stephens of the same institution, now retired, assisted in a similar manner by calling attention to the occurrence of important species in certain parts of the region, and also prepared for us a large list of Pleistocene fossils from Spanish Bight. Mr. Eric Knight Jordan assisted during the initial stage of the field work, as related above.

[1] For an excellent compilation of the general facts concerning the history and features of San Diego, Calif., see, "San Diego, A California City", Amer. Guide Series (sponsored and publ. by The San Diego Historical Society, San Diego, Calif.), x + 138 pp., frontispiece, 25 illustrations, 6 maps, 1937.

Messrs. Frank B. Tolman and Ernest H. Quayle assisted us materially by collecting large faunas and pointing out some interesting geological features. Mr. Tolman gave helpful advice in regard to the Eocene stratigraphy, and Mr. Quayle has spent much time in assisting us with the illustrations. Dr. John E. Wolff, Professor of Geology Emeritus at Harvard University, prepared a short description of several crystalline rocks, and Dr. Gordon A. Macdonald, now of the U. S. Geological Survey, made some interesting petrographic and sedimentary studies for us. The Associated Oil Company permitted the use of well logs of this area which Mr. C. C. Church, paleontologist of that company, kindly examined for us. We here wish to acknowledge the cooperation of Mr. J. E. Pettijohn who kindly permitted us to examine the geologic reports of Mr. George H. Doane on the San Diego Gas and Petroleum Corporation's Holderness No. 1 Well, which was drilled near the mouth of the Tia Juana River. Mr. Clinton G. Abbott, Director of the Museum of the San Diego Society of Natural History, permitted us to use all the facilities of that institution and cooperated in an important manner during the publication of the paper. Dr. G. Dallas Hanna of the Department of Paleontology, California Academy of Sciences, aided us many times with his valuable advice and cooperation. Both authors began this work while students of the late Dr. James Perrin Smith, Professor of Paleontology at Leland Stanford Jr. University, and they both remember his kind encouragement at that time. We wish to express our appreciation to Dr. Olaf P. Jenkins, Chief Geologist of the Division of Mines of the State of California, and to Mr. A. L. Ransome and Mr. E. Drew of the same department, for advice and assistance in the preparation of the geologic map and sections. Mr. F. P. Farquhar kindly furnished information regarding the construction of the first dike at San Diego by Derby. Secretarial work on the manuscript by Miss Winifred O'Neill is the result of work accomplished during a government Works Progress Administration Project No. 8569. The authors are grateful for the research grants from the University of California at Los Angeles received during the progress of this work.

HISTORICAL REVIEW OF THE LITERATURE

The sedimentary beds in the vicinity of San Diego have been mentioned or briefly described by many authors. Most of the early reports were brief notes based upon limited field observations or were mere descriptions of or references to some of the fossils that occur there. Tyson,[2] who made a short trip to San Diego about 1850, mentioned "that sedimentary rocks prevailed on the hills near the sea, and that there was an extensive diffusion of diluvial drift." T. A. Conrad's description[3] of *Ostrea vespertina* from "near San Diego, California," seems to have been the first paleontologic notice of the fossiliferous sedimentary beds in that region. In this paper, he referred the beds containing this Pliocene oyster questionably to the Miocene and in three later papers[4] he also considered these beds to belong to the Miocene. In 1856, William P. Blake,[5] a pioneer geologist of the West, referred briefly to the general features of the region about San Diego and included with his report a small scale geologic map of southern California. He also mentioned certain fossils which he believed to be of Miocene age but which are now known to be of Eocene age. In two subsequent papers he likewise mentioned Tertiary fossils, probably the Eocene fossils which occur plentifully near the older part of the City of San Diego, near the San Diego Mission, and at various other localities. The Tertiary beds in the vicinity of San Diego were also mentioned by Antisell.[6]

In connection with the survey of the United States-Mexican Boundary made about the middle of the last century, Emory[7] made a limited study of the geology in the vicinity of San Diego and briefly described the seaward dipping sedimentary beds of "coarse sand, clay, or marl, with occasional beds

[2] Tyson, P. T., "Geology and Industrial Resources of California," Senate Executive Document 47, 31st Congress, 1st Session, 1850 (reprinted with an introduction, published by Wm. Minifie and Co., Baltimore, 1851), p. 20. See also Lieut. E.O.C. Ord, p. 123.

[3] Conrad, T. A., Journ. Acad. Nat. Sci. Philadelphia, Ser. 2, Vol. 2, p. 300, 1854.

[4] Conrad, T. A., House Document 129, Projected Vol. 3, 33rd Congress, 1st Session, 1855, pp. 11-18. — U. S. Pac. R. R Repts., Vol. 5, pp. 322-327, 1856-1857. — Rept. U. S. Boundary Surv., Vol. 1, pt. 2, p. 160, 1857.

[5] Blake, W. P., Senate Ex. Doc. 22, 34th Congress, 1st Session, Rept. Supt. Coast Surv., pp. 395-396. Map 60, 1855 (issued 1856). — Proc. Amer. Assoc. Adv. Sci., Vol. 9, p. 224, 1856. — U. S. Pac. R. R. Repts., Vol. 5, pp. 176-177, 1857.

[6] Antisell, T., U. S. Pac. R. R. Repts., Vol. 7, p. 119, 1856

[7] Emory, W. H., Rept. of U. S. Boundary Surv., Vol. 1, pt. 2, p. 85, 1857.

of interstratified pebbles" and noted particularly a thirty foot fossiliferous layer exposed in the steep bluffs which bound the lower part of the river valley at San Diego. This layer may have been the fossiliferous Eocene exposed on the sides of San Diego River Valley though on the south side the overlying Pliocene is likewise fossiliferous. This may be said to have ended the period of pioneer geological work during which much important information of a reconnaissance nature of various parts of California was obtained, largely in connection with the expeditions sent out by the War Department to make surveys for proposed railroad routes in what was then referred to as the "far West."

Years later, after the business district of San Diego had moved from its former position (now called "Old Town"), near the mouth of San Diego River Valley,[8] to a position several miles south on the shore of San Diego Bay, a well was dug in the bottom of a small canyon back of the City in order to obtain water to supplement the meager supply for the small but rapidly growing settlement. This well, which was in City Park (now Balboa Park), penetrated a fossiliferous fine-grained sandstone from which Henry Hemphill, an early local conchologist, obtained a considerable collection of fossil shells. Part of this collection was sent to the late W. H. Dall who published a paper[9] in 1874 in which he discussed the "San Diego beds" and listed 51 definitely identified species and eighteen additional not specifically identified forms. He made the following comment as to the geologic age:

"The age of the deposit, in general terms, may be taken as Pliocene; though it is evident that the different epochs of the Tertiary are not as sharply separated on this coast as in some other parts of the world."

A few years later Dall[10] again listed the fauna from the San Diego well and added the descriptions of six new species. He noted Hemphill's suggestion of the equivalence of the beds in the well from which the fossils were obtained, to the fossiliferous beds at Pacific Beach several miles to the northwest. Dall again gave the age as Pliocene.

In 1886 a note in the West American Scientist,[11] presumably by its editor, C. R. Orcutt, stated:

"The peninsula in front of San Diego city is being improved by a company who propose making it a popular resort and to which the name Coronado Beach has been applied. In boring for Artesian water, a strata [stratum] of sand was found containing numerous fossil shells of the later tertiaries. The most prevalent species were *Phasianella compta, Ostrea lurida* and *Anomia lampe* in the order named. The strata was found at a depth of nearly seventy feet." This occurrence was mentioned by Ellis,[12] who stated that W. A. English regarded the three species as belonging to the lower Pliocene. However *Tricolia compta* Gould is not definitely known below the Pleistocene and the other two species are much more common in the Pleistocene than in the Pliocene, hence it is almost certain that the beds encountered in this well are of Pleistocene age.

In a catalogue of California fossils, published in 1888, J. G. Cooper[13] listed numerous species from the Pliocene of San Diego, some of them being reported for the first time in those beds. In the same year Goodyear[14] discussed the geology of San Diego County in which paper the following statement occurs:

"Commencing at the Mexican boundary line, the Mesa formation, of pleiocene age, is some ten or twelve miles wide, and from thence it forms an uninterrupted belt of varying width for a distance of more than fifty miles along the coast towards the northwest, or as far as the Santa Margarita River." It is apparent that Goodyear included beds other than the Pliocene, for most of the mesa north of

[8] Often known as Mission Valley but not to be confused with a Mission Valley further north in the San Luis Rey River Valley.

[9] Dall, W. H., Proc. Calif. Acad. Sci., Vol. 5, pp. 296-299, 1874. According to Henry Hemphill, the collector, the fossils were obtained from the well at a depth between 140 and 160 feet. The matrix was said to be hardly consolidated in some parts and quite hard in others. The occurrence of these fossils was first mentioned by R. E. C. Stearns (Proc. Calif. Acad. Sci., Vol. 5, no. 10, pp. 153-55, Oct., 1873).

[10] Dall, W. H., Proc. U. S. Nat. Mus., Vol. 1, pp. 10-16, 26-30, 1878.

[11] Orcutt, C. R., West Amer. Scientist, Vol. 2, no. 15, p. 32, 1886.

[12] Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, p. 64, 1919.

[13] Cooper, J. G., Calif. State Mining Bureau, 7th Ann. Rept. State Mineralogist, pp. 223-308, 1888. Parts 2, 3, 4 and 5 of this catalogue appeared as Bulletin 4, Calif. State Mining Bureau, 65 pp., 6 pls., 1894.

[14] Goodyear, W. A., Calif. State Mining Bureau, 8th Ann. Rept. State Mineralogist, p. 522, 1888.

San Diego River Valley is of Eocene age.

In 1889 Orcutt[15] published a list of Tertiary fossils from localities such as Pacific Beach, False Bay (now called Mission Bay), Ocean Beach and Roseville, but he added nothing new on correlations. Some of the localities are probably Pleistocene. At Pacific Beach Orcutt noted three imperfectly defined members. The oldest he stated was a sandstone with moulds of various bivalves and imperfect valves slightly resembling oysters; the second, distinctly softer beds, containing *Opalia, Janira, Pecten, Terebratula?*; the third, younger beds more recent in character, containing most of the other species. Probably his oldest bed was Eocene, the second Pliocene, and the third either Pliocene or Pleistocene.

A number of the West American Scientist for 1900 (Vol. 10, no. 4, whole no. 86, pp. 17-19), contains a discussion of the geology of the San Diego region by H. W. Fairbanks. Some of the structural features are mentioned and particular mention is made of the changes in elevation which took place in the late Tertiary and Quaternary. Fairbanks mentioned a "Mesa formation" which no doubt included the Pliocene beds. This discussion in the West American Scientist appears to be a quotation from the San Diego Sun of April 16, 1891.

A paper on correlation by Dall and Harris[16] was published in 1892, in which they gave a brief review of the existing literature concerning the San Diego region and quoted Dall's original determination of the Pliocene age of the fossils from the San Diego well.

At this time some of Fairbanks' geological work for the California State Mining Bureau was being published. In one paper[17] he discussed the geology in the vicinity of San Diego and referred to strata of Quaternary, Pliocene and questionably Miocene age. He gave a good outline description of the basin in which the San Diego beds were deposited and stated that apparently Point Loma and the Soledad Hills formed the western and the northern margins of the basin. He also pointed out that a recent uplift had taken place along the ocean side of the mesa. In a second paper[18] he stated:

"The Miocene is not positively recognized near San Diego, but the mesas along the eastern side of the bay on which the city is situated are filled with Pliocene fossils; the strata being separated from the Chico-Tejon by a small non-conformity."

In 1893 an important paper[19] on the post-Pliocene diastrophism of the coast of southern California by A. C. Lawson was published. This paper contains an excellent description and discussion of the marine terraces in the San Diego region. Lawson believed the San Diego beds to be in part a portion of a delta of Pliocene age, the age determination being based upon a comparison with Miocene strata elsewhere and upon Dall's paleontologic evidence.

A number of later papers have contained indirect references to the San Diego beds in connection with correlations of other deposits on the Pacific coast. Among these may be mentioned papers by Dall,[20] Arnold,[21] Rivers,[22] J. P. Smith,[23] Louderback,[24] Merrill,[25] Clark and Twitchell,[26] Moody,[27]

[15] Orcutt, C. R., West Amer. Scientist, Vol. 6, whole no. 45, pp. 70-71, 1889.

[16] Dall, W. H., and Harris, G. D., U. S. Geol. Surv., Bull. 84, p. 216, 1892.

[17] Fairbanks, H. W., Calif. State Mining Bureau, 11th Ann. Rept. State Mineralogist, 1891-1892, pp. 96-97, 1 map, 1893.

[18] Fairbanks, H. W., Amer. Journ. Sci., Ser. 3, Vol. 45, p. 477, 1893. A year later Cooper stated that the fossils found by Fairbanks indicated that the whole mesa was of Pliocene age. See Calif. State Mining Bureau, Bull. 4, p. 52, 1894.

[19] Lawson, A. C., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 1, pp. 115-160, pls. 8, 9, Dec., 1893. See page 119

[20] Dall, W. H., U. S. Geol. Surv., 17th Ann. Rept., pt. 1, p. 476, 1895. In this paper Dall reported fossils collected by Diller in northwestern Oregon, stating that some of them belonged to "the Pliocene (horizon of Pacific Beach, San Diego, Cal.)."

[21] Arnold, R., Mem. Calif. Acad. Sci., Vol. 3, pp. 13, 57-64, 1903. — U. S. Geol. Surv., Prof. Paper 47, p. 28, 1906.

[22] Rivers, J. J., Bull. Southern Calif. Acad. Sci., Vol. 3, no. 5, p. 69, 1904. Rivers mentioned sandstones in the Santa Monica Mountains which he believed represented the San Diego Pliocene in that area.

[23] Smith, J. P., Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, no. 4, pp. 149, 151, 1919.

[24] Louderback, G. D., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 7, no. 10, p. 223, 1913. This paper contains a correlation table of west coast Tertiary formations, in which the San Diego formation is considered equivalent to the Purisima formation of central California, since reference is made to "Sandstones of San Diego and Half Moon Bay with Pecten healeyi." — Trans. San Diego Soc. Nat. Hist., Vol. 2, no. 3, pp. 87-97, 1916.

[25] Merrill, G. P., Calif. State Mining Bureau, 14th Ann. Rept., pt. 5, pp. 639-644, 1916. Issued as a separate, Dec., 1914. Contains a correlation table and discussion of the geology of the San Diego region.

[26] Clark, W. B., and Twitchell, M. W., U. S. Geol. Surv., Monograph 54, p. 102, 1915. In a correlation table the San Diego formation is placed below the Merced and given as equivalent to the Caloosahatchee and Nashua of the eastern Gulf area, and the Waccamaw of the south and middle Atlantic border.

[27] Moody, C. L., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 10, no. 4, p. 50, 1916

B. L. Clark,[28] Kew,[29] Carson,[30] Hertlein,[31] E. K. Jordan and Hertlein,[32] Waterfall,[33] Pressler,[34] Woodring,[35] Soper and Grant,[36] Reed,[37] and others.[38]

In an important correlation paper Dall[39] stated that the Pliocene marls in the San Diego well also occur below the Pleistocene beds at Pacific Beach, along the shores of False Bay and on the Coronado Peninsula. He stated that the horizon could be recognized at various other localities to the north, including Deadman Island, Harbor Hill, San Pedro, and also at Todos Santos Bay, Lower California. In the correlation table Dall placed the San Diego beds below the Merced group and indicated them to be equivalent to the Caloosahatchee beds of the Gulf States and to the Waccamaw beds of the Atlantic coast. The latter he considered in general correlative with the Crag beds of England. A few years later[40] he remarked that the only known strictly defined Pliocene marine fauna of California was that at San Diego. He called attention to the difference between the Pliocene and Recent faunas of San Diego, and the Pliocene and Recent faunas of northern California and Oregon, many of the San Diego Pliocene species being known in the living fauna only in the Gulf of California.

Ralph Arnold[41] appears to have been the first to use the name "San Diego Formation" for the Pliocene strata at San Diego. In his important memoir[42] on the paleontology and stratigraphy of the San Pedro region he included the results of his collecting and geological field work in the San Diego district, including faunal lists of species obtained from several Pliocene and Pleistocene localities—lists which have been used with little additions or alterations by later writers almost up to the present time. In a series of important later papers[43] incorporating the results of his work for the U. S. Geological Survey he republished the faunal lists of species occurring at San Diego, described new species from there, or made correlations which mentioned equivalents of the San Diego formation in other parts of California. Some of his opinions on correlations will be briefly summarized here. In 1906 he considered the lower part of the San Diego formation to be equivalent to the middle and upper part of the Purisima formation, and the upper part of the San Diego formation equivalent to the Merced. In 1907 he considered the Third Street Tunnel (Los Angeles) and Temescal Canyon (near Santa Monica) faunas to be of "San Diego" age. In several papers he referred to the middle

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28 Clark, B. L., Journ. Geol., Vol. 29, p. 610, 1921. — Proc. First Sci. Confer. Pan-Pacific Union, pt. 3, Bernice P. Bishop Mus., Special Publ. 7, pt. 3, p. 817, 1921.

29 Kew, W. S. W., Bull. Amer. Assoc. Petrol. Geol., Vol. 7, pp. 419-420, 1923. The Saugus formation of the Ventura basin believed to be equivalent to the San Diego formation. — U. S. Geol. Surv., Bull. 753, p. 89, 1924. Saugus and San Diego formations believed to be equivalent.

30 Carson, C. M., Pan-Amer. Geologist, Vol. 43, no. 4, pp. 265, 268, 1925. Contains a list of San Diego Pliocene fossils

31 Hertlein, L. G., Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, no. 1, p. 6, 1925. Pliocene of Cedros Island, Lower California, Mexico, stated to be in general equivalent to the San Diego Pliocene of Pacific Beach.

32 Jordan, E. K., and Hertlein, L. G., Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, no. 14, pp. 422-423, 1926. Relationship between the Pliocene and Eocene at Pacific Beach clarified and Pliocene of San Diego, Turtle Bay and Cedros Island stated to represent approximately middle Pliocene or the lower part of the upper Pliocene.

33 Waterfall, L. M., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, no. 3, pp. 80-81, April 6, 1929. Upper Pico fauna of Ventura County correlated with Pliocene of San Diego.

34 Pressler, E. D., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, no. 13, p. 334, Sept. 30, 1929.

35 Woodring, W. P., Proc. Calif. Acad. Sci., Ser. 4, Vol. 19, no. 6, pp. 57-64, July 15, 1930. San Diego Pliocene equivalent noted north of Simi Valley.

36 Soper, E. K., and Grant, IV, U. S., Bull. Geol. Soc. Amer., Vol. 43, p. 1041-1068, Dec., 1932. See pp. 1066-1067 San Diego Pliocene considered in part equivalent to the Third Street Tunnel beds of Los Angeles, and also in part equivalent to the Pliocene of Elsmere Canyon.

37 Reed, R. D., "Geology of California." Published by Amer. Assoc. Petrol. Geol., Tulsa, Oklahoma, May, 1933. See pp. 227-228. This important work on the geology of California contains a brief discussion of the San Diego formation.

38 A number of very brief references to the Pliocene of San Diego occur in the literature but need not be included here, since little new information is contained in them.

39 Dall, W. H., U. S. Geol. Surv., 18th Ann. Rept., pt. 2, opp. p. 334, p. 337, 1898

40 Dall, W. H., in Diller, J. S., U. S. Geol. Surv., Bull. 196, pp. 37-39, 1902.

41 Arnold, R., Journ. Geol., Vol. 10, p. 130, 1902.

42 Arnold, R., Mem. Calif. Acad. Sci., Vol. 3, pp. 13, 57-59, 1903.

43 Arnold, R., U. S. Geol. Surv., Prof. Paper 47, p. 28, 1906. — Proc. U. S. Nat. Mus., Vol. 32, pp. 527, 544, June, 1907 - In Eldridge, G. H., and Arnold, R., U. S. Geol. Surv., Bull. 309, pp. 23-24, Oct. 23, 1907. — Smithson. Miscell. Coll., Vol 50, pp. 431, 445, Dec. 13, 1907. — In Arnold, R., and Anderson, R. V., U. S. Geol. Surv., Bull. 322, pp. 148, 152, 154, Jan. 4, 1908. — Proc. U. S. Nat. Mus., Vol. 34, pp. 384-385, Aug. 8, 1908. — Journ. Geol., Vol. 17, no. 6, opp. p. 532, 1909. - U. S. Geol. Surv., Bull. 396, pp. 9, 48, 1909. — In Arnold, R., and Anderson, R. V., U. S. Geol. Surv., Bull. 398, p. 48. 1910. — The correlation table in this paper was also cited by B. Willis in U. S. Geol. Surv., Prof. Paper 71, p. 818, 1912.

Fernando fauna of the Ventura basin as probably equivalent to the lower part of the San Diego formation and recognized Pliocene beds of San Diego age, or approximately San Diego age, or containing species occurring in the San Diego Pliocene and suggestive of similar age, in the Santa Monica region and in other basins. In 1908 Arnold listed "*Agasoma stanfordensis*" questionably from the San Diego formation on Mission Grade, near the head of Sixth Street, San Diego. The *Agasoma*-like species which occurs at that locality is a *Trophosycon*[44] in the lower part of the Pliocene beds. In general, Arnold's correlations have been but little changed by subsequent work.

Aguilera[45] in 1906 mentioned a formation at Tijuana, Lower California, Mexico, which he stated was the equivalent of the Purisima of California and which he considered to belong at the base of the Pliocene. This no doubt referred to the southern extension of the San Diego formation on the south side of the International Boundary.

In 1910 J. P. Smith[46] placed the San Diego formation in the lower Pliocene and correlated it with the middle Fernando of Los Angeles, Ventura, and Santa Barbara Counties, lower and middle part of the Tulare formation of the San Joaquin Valley, lower and middle part of the Paso Robles formation at the type section in Salinas Valley, upper part of the Purisima at Half Moon Bay, and middle part of the Berkeleyan of the Mount Diablo region.

In his later classic paper on the climatic relations of the Tertiary and Quaternary faunas of the California region, Smith[47] gave a list of fossil mollusks from the San Diego formation and discussed the climatic and stratigraphic relations of the fauna to other marine Pliocene faunas of California. He correlated the San Diego Pliocene with the Merced of Seven Mile Beach (just south of San Francisco) and considered it to be the southern equivalent of that series. He also stated, following Dall, that this zone is found in the region of Todos Santos Bay, Lower California. However, beds of that age have not been reported from near Todos Santos Bay by later workers. It is not known what the original basis of this age determination may have been. Smith considered the fauna from the City of Los Angeles described by Moody[48] to be of the same age as that of the San Diego Pliocene, but it is now believed that Moody's fauna is later in age than that of the San Diego formation.[49] According to Smith the European equivalents of the San Diego and Merced are the Red Crag of England, Scaldisian of Belgium, and Astian of Italy.

In a paper[50] on the geology and ground waters of the western part of San Diego County, Ellis included considerable information on the physiography and stratigraphy of the San Diego Tertiary basin. The geological map is of considerable interest but the boundary of the Pliocene formation is inaccurate as it includes considerable Eocene north of San Diego River Valley and probably some Pleistocene elsewhere.

Marcus A. Hanna's report[51] on the geology of the La Jolla Quadrangle, an area consisting largely of Eocene strata, contains a short but significant discussion of the Pliocene beds occurring in small areas in the southern part of that Quadrangle. Hanna mapped the Pliocene-Eocene contact with considerable accuracy and thus removed much Eocene from the area now known to be occupied by the San Diego formation, which had been incorrectly placed there by others due to scarcity of fossils and lack of sufficient field work.

Hertlein[52] in 1929 completed a thesis which was submitted to the Leland Stanford Jr. University,

[44] The lower part of the Pliocene as exposed at Elsmere Canyon contains a fossiliferous zone which includes *Trophosycon*. This fossil zone is within 100 feet stratigraphically above the Pliocene-Eocene contact. This affords a striking similarity to the Pliocene beds at San Diego.

[45] Aguilera, J. G., Cong. Geol. International, 10th Session, Mexico, 1906, Vol. 10, fasc. 1, pt. 6, p. 244, 1907.

[46] Smith, J. P., Journ. Geol., Vol. 18, no. 3, opp. pp. 217 and 226, 1910.

[47] Smith, J. P., Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, no. 4, pp. 150-152, 1919. See also, Calif. State Mining Bureau, Bull. 72, table opp. p. 16, p. 38, 1916.

[48] Moody, C. L., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 10, no. 4, pp. 39-62, pls. 1, 2, 1916.

[49] This correlation was recently discussed by Soper, E. K., and Grant, IV, U. S., Bull. Geol. Soc. Amer., Vol. 43, pp. 1041-1068, 1932.

[50] Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, pp. 56-68, 1919

[51] Hanna, M. A., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, no. 7, pp. 216-218, 1926.

[52] Hertlein, L. G., "The Geology and Paleontology of the Pliocene of San Diego, California," a thesis presented to the Department of Geology of Leland Stanford Junior University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1929. — Stanford Univ. Bull., 5th Ser., Vol. 4, no. 78, pp. 81-85, July 31, 1929.

entitled "The Geology and Paleontology of the Pliocene of San Diego, California," and an abstract of this was published the same year. He concluded that the San Diego Pliocene could be correlated with the Pliocene of Elsmere, Holser, and Pico Canyons, which he considered to be lower Pliocene in age. The Pliocene fauna at Cedros Island and Turtle Bay in Lower California was said to be the closest equivalent to the south.

Grant and Gale, in their memoir on the Pliocene and Pleistocene Mollusca of California, reported many species from the San Diego formation, and Gale[53] gave a discussion of the stratigraphy of the San Diego basin based mostly on field data furnished by Grant. A geologic map[54] of California prepared under the direction of Dr. Olaf P. Jenkins was published in 1938. The geology of the San Diego region on this map is essentially as it appears in the unpublished thesis of Hertlein. A brief summary of some of the salient features of the geology of the area included in the present paper, with numerous well records, was published by the present authors[55] in a recent number of the California Journal of Mines and Geology.

A number of papers* not mentioned above contain brief references to the San Diego Pliocene, but generally they merely restate the conclusions or opinions of others. A few contain descriptions of new or supposedly new San Diego Pliocene fossils, but these latter will be included in the references under the particular species in the systematic part of the present work.

The name San Diego formation has been used by Meyerhoff[56] for upper Cretaceous beds in the West Indies. That formational name has had many years prior use in California, and it would appear to be advisable to rename Meyerhoff's formation in order to avoid possible confusion.

PHYSIOGRAPHY

GENERAL DESCRIPTION

The area considered in this report can be divided physiographically into two parts, the coastal mesa region on the west and the mountainous region on the east. These two parts are very distinct, both in their topography and their geology, the boundary between them being both a topographic and a geologic unconformity (see physiographic block diagram). Each part has had a somewhat different history and each is comprised of different rocks. They will be considered separately, although a complete physiographic picture of the whole area can be obtained only by an understanding of the genetic connection which exists between them. Some of the features of the coastal mesa region have been derived from the region to the east, and both, to some extent, have been influenced by the same forces and geologic processes. The climate, particularly the rainfall, has been of importance in determining the present relief features of both regions, hence it seems well to present a brief and general description of the climate at the beginning of this discussion.

CLIMATE AND RAINFALL

The climate of the San Diegan region varies considerably with elevation above sea level and distance from the coast. Statistics may be obtained from official government weather reports, so that here it will be necessary only to give such general facts as might have a bearing upon weathering

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[53] Gale, H. R., in Grant, IV, U. S., and Gale, H. R., Mem. San Diego Soc. Nat. Hist., Vol. 1, pp. 45-49, 1931.

[54] State of Calif., Dept. Nat. Resources, Division of Mines. Geologic Map of Calif., prepared by Olaf P. Jenkins. Ed. 1, 1938.

[55] Hertlein, L. G., and Grant, IV, U. S., "Geology and Oil Possibilities of Southwestern San Diego County," Calif Journ. Mines and Geol., Vol. 35, no. 1, 35th Rept. Calif. State Mineralogist, pp. 57-78, 8 figs. in text, Jan., 1939 [received at library of the California Academy of Sciences Aug. 23, 1939].

* After the present paper was submitted for publication, a paper by W. P. Woodring, R. B. Stewart, and R. W. Richards appeared, entitled "Geology of the Kettleman Hills Oil Field, California," Prof. Paper 195, U. S. Geol. Survey, 1940 [issued June 7, 1941]. A brief discussion of the fauna of the Pliocene of San Diego is given on pp. 112-113. See also correlation table opp. p. 112. See also correlation chart by U. S. Grant, IV, and L. G. Hertlein, State of Calif. Dept. Nat. Resources, Div. Mines, Bull. 118, preprint of pt. 2, p. 202, Aug. 1941 (issued Sept. 11, 1941); also preprint of pt. 3, pp. 367-369, 1 text fig., March, 1943 (issued July 1, 1943).

[56] Meyerhoff, H. A., Science, New Ser., Vol. 71, no. 1838, p. 323, 1930. Also, New York Acad. Sci., Sci. Surv. Porto Rico and the Virgin Islands, Vol. 2, pt. 3, pp. 289-290, 1931. The type locality of the San Diego formation is at Punta San Diego, Porto Rico. Upper Cretaceous.

and the other processes of erosion.[57] The coastal region has an equable temperate dry climate with moderate precipitation occurring chiefly between the months of October and April.[58] At San Diego the average annual rainfall is about ten inches. All of the mesa region described in this report is within this coastal belt of semi-aridity. The higher mountains of central and eastern San Diego County have a heavier rainfall and a much less equable climate, with a noticeably greater diurnal and seasonal range of temperature. The coastal belt rarely experiences freezing temperatures in winter nor oppressively hot days in summer, but the higher mountains to the east frequently receive a few inches of snowfall during winter, and during summer the temperature, in some of the valleys, occasionally reaches 100 F. The higher ridges and peaks act as a trap for the eastward drifting rainstorms and a precipitation of over 40 inches per year occurs on the western slopes of such mountains as the Cuyamacas and Palomar.[59] A rainfall of over twenty inches per year occurs throughout a north-south belt within the heart of the higher elevations. Lee[60] has assembled considerable data on precipitation in San Diego County[61] to which the reader is referred for more information than seems justifiable to be included here.

THE COASTAL MESA REGION

The coastal mesa region extends north and south, parallel and adjacent to the coast line throughout the San Diego area and continues many miles beyond its northern and southern limit. On the west this mesa region is truncated by shoreline processes where it extends to the beach, or breaks off more gradually in a series of marine terraces where separated by bay or coastal plain from the present sea. The coastal plain is of such limited extent that it is considered a minor subdivision of the mesa region. In width this region varies from about 6 to 14 miles and in height from over 800 feet (the summit of Soledad Mountain) to near sea level; but the nearly flat-topped, slightly dissected mesa that forms the most conspicuous feature has an elevation ranging from about 300 to 550 feet.

The coast line within the area considered here is modified by two promontories, the broad northern

[57] The climate has not only directly influenced the more important erosive processes but has determined the type of vegetation. This has had, in turn, a bearing on the physiographic processes. Lichens, ordinarily such inconspicuous plants, here form an almost continuous protective mat over parts of the mesa region, and appear to greatly retard rain wash and sheet-flood erosion, prevent the rapid development of gullies, and thereby facilitate the accumulation of soil and deeply weathered mantle rock. For example, on the mesa east of Paradise Valley and north of the Sweetwater River Valley a lichen-moss cover is very prominent. Specimens collected early in 1938 were submitted to Professor Carl Epling of the Department of Botany, University of California at Los Angeles, who identified the flora as follows: "The vegetative part of a moss thus far undeterminable; a fern, *Selaginella cinerascens;* and two lichens, *Parmelia conspera* variety *stenophylla* and *Urceolaria scruposa.*" This vegetative mat holds the surface of the soil firmly in place, delays sheet-flood run-off, and by lessening the turbidity of run-off, facilitates percolation of rain water into the soil. A decrease in mud content has been shown to have an important bearing on infiltration of water into the soil. See: Loudermilk, W. C., "Further studies of factors affecting surficial run-off and erosion," Proc. Internat. Congr. Forestry Exper. Stations, 1929, pp. 606-628, 14 figures. Reviewed by Kirk Bryan in Zeitschrift für Geomorphologie, Vol. 6, 1931.

[58] From 1908 to 1933 about 95% of the annual rainfall at San Diego occurred between October and April inclusive and almost 74% between December and March inclusive. (See State of California, Dept. Public Works, Publ. Division of Water Resources, Bull. 48, table 3, 1935. This paper contains considerable information on rainfall, run-off, and water resources in general of San Diego County). R. J. Russell, in his studies of climate, using the system of W. Köppen (Grundriss der Klimakunde, Berlin and Leipzig, 1931) and the Köppen-Geiger Klimakarte der Erde (Gotha, Justus Perthes, 1928), classified the climate in the San Diego coastal region as BWhn and the foothills as BSh. The BWhn climate is essentially an arid, foggy, coastal desert, and the BSh is an arid steppe type. (See Russell, R. J., "Dry Climates of the United States. I. Climatic Map," Univ. Calif. Publ. Geography, Vol. 5, no. 1, pp. 1-41, pl. 1, 8 text figs. Jan. 13, 1931. See especially p. 39, and pl. 1). These two climates continue along the west coast of Lower California, Mexico, with variable width, to below 31° North Latitude. (See Meigs, 3rd, Peveril, "The Dominican Mission Frontier of Lower California," Univ. California Publ. Geography, Vol. 7, pp. 1-232, Nov. 30, 1935. See especially fig. 3 and p. 15). Both these climates occur in Nelson's Upper Sonoran Life-zone in Lower California. (See Mem. Nat. Acad. Sci., Vol. 16, Mem. 1, pl. 32, 1922 [separate dated 1921]).

[59] Hot Springs Mt., northeast of Warner's Hot Springs, has the two highest peaks in San Diego County, namely Black Rabbit Peak, 6,633 feet, and Hot Springs Peak, 6,535 feet, which are separated by a short saddle. The only other point over 6,500 feet high is Cuyamaca South Peak, 6,527 feet. There are probably a dozen additional peaks in the County with an elevation of 6,000 feet or more. Some of the better known are Laguna Peak, 6,375; Monument Peak, 6,321; San Ysidro Mt., 6,147; Palomar Mt., 6,138; and Cuyamaca North Peak, 6,030. (Information received from Mr. B. B. Moore in the office of E. R. Childs, San Diego County Surveyor; Mr. George Buxton, acting for N. J. Farrell, Forest Supervisor, Cleveland National Forest, United States Department of Agriculture; and Mr. L. W. Deewall, San Diego County Planning Engineer. February and March, 1943).

[60] Lee, C. H., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, pp. 76-99, with several tables and plates, 1919. See also, Calif. Div. Water Resources Publ., Bull. 48, 1935.

[61] Instrumental records of annual precipitation at San Diego began with the season 1850-1851. An interesting study of earlier rainfall fluctuations in southern California has been published by the Metropolitan Water District of Southern California. See Lynch, H. B., "Rainfall and Stream Run-off in Southern California since 1769," Los Angeles, Calif., Aug., 1931.

one formed by the mass of Soledad Mountain near La Jolla, the southern one formed by the isolated north and south trending Point Loma, and two bays, shallow Mission Bay (formerly called False Bay) between Soledad Mountain and Point Loma, and the larger and deeper San Diego Bay, which is protected by Point Loma and a long sand spit called the Silver Strand, Coronado and North Island. The details of coast-line contour can be readily seen on the map (page 50) or on the physiographic block diagram. The latter also shows the San Diego Mesa and other relief features in the region.

The eastern boundary of the mesa region is determined by the contact of the overlapping edge of the Tertiary (Eocene or Pliocene) sediments upon the older crystalline rocks that form the foothills of the mountainous region to the east. This boundary line becomes somewhat indefinite in detail where the feather edge of the eastward thinning Tertiaries becomes a mere veneer of soil resting upon the older rocks beneath.

THE TERRACES

San Diego Mesa

The most conspicuous topographic feature of the coastal portion of the San Diego region is the broad, relatively flat mesa which occupies most of the area included in the San Diego and La Jolla Quadrangles. This mesa, here referred to as the San Diego Mesa, is but one of several marine terraces or plains of marine denudation and deposition, the higher ones, of greater age, being considerably dissected and less noticeable, the lower ones, developed on the western margin of the mesa, being of relatively slight area though readily seen where not removed by later erosion.

The San Diego Mesa, the principal terrace, is physiographically a unit, though its separation by the larger stream valleys has resulted in different names being applied to different parts (see Plate 3). Thus the mesa south of Otay Valley is known as the Otay Mesa and the one north of San Diego River as the Linda Vista Mesa or Linda Vista Terrace.[62] Both of these mesas were at one time continuous before stream erosion began the work of dissection. In the south this mesa has been elevated higher and apparently more rapidly than in the north, for near the Mexican Boundary (Otay Mesa) the surface is over 550 feet above sea level, whereas the western portion of the mesa just south of San Diego River Valley attains an elevation but little over 300 feet; and the greater vertical interval between the lower terraces in the south indicates a more rapid uplift there.

The surface of the San Diego Mesa, where unmodified by erosion subsequent to emergence and uplift, slopes gently toward the west except in the southern part, where Otay Mesa has either been tilted slightly eastward or its eastern surface lowered by erosion more than its western.[63] This mesa, when viewed from a point on its surface, appears almost like a featureless plain, the river valleys and canyons being below the line of vision. However, close inspection reveals some slight irregularities in detail, such as gentle undulations, long low ridges, some of which are believed to be beach ridges, and occasional areas of small hillocks or prairie mounds (Plate 6). The gentle undulations may be due in part to differences in rate of weathering and erosion or to irregularities of uplift, but generally the exposures of the underlying beds are inadequate to determine the cause. The hillocks, which are well developed on parts of the Linda Vista Terrace and the mesa west of Sweetwater Reservoir and the Otay Mesa, often attain a height of 3 or more feet and a basal diameter of 10 to 20 feet. Small ephemeral pools of water collect between them during spring rains. These prairie mounds or hillocks are not confined to the tops of the mesa but are sometimes distributed over its gentle marginal slopes into shallow broad swales which, in some cases, may represent stream valleys of an older cycle than the present one. It seems likely that their origin is connected with wind action and former vegetation, possibly the accumulation of aeolian sand around bushes, or irregular deflation between them. The

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62 Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, pp. 27-28, pl. 7, 1919. This paper contains an interesting description of the physiography of western San Diego County. See pp. 20-50.

63 We did not observe any eastward dip of the strata underlying the Otay Mesa which could be relied upon as significant. A one degree eastward dip on the north side of Sweetwater Valley near its mouth is probably local. The eastward slope of the surface appears to be due to erosion.

abundance of these mounds suggests a rather widespread condition different from the present,[64] possibly a superabundance of loose sand or finer-grained material exposed to wind transportation soon after the sea regressed from the present mesa top and while it was actively cutting rapidly widening benches at slightly lower levels, which are now represented by the terrace 50 feet below the top of the Otay Terrace and the lower ones mentioned by Ellis. The rather uniform distribution of these mounds would suggest the even distribution of former vegetation as a controlling factor. An examination of the soil map of this area[65] might lead one to suspect that the prairie mounds were connected in some way with the type and degree of weathering of the soil series on which they are formed. For example, they are common on strongly or maturely developed secondary soils such as the Olivenhain series, the Las Flores loamy fine sand and the Redding series, which have been mapped in the mesa lands of western San Diego County. These soils have an acidic uppermost layer, a clay or hardpan subsoil, and occur on elevated terraces both north and south of the City of San Diego where prairie mounds also occur. Such soils promote the growth of widely spaced bushes or clumps of vegetation and in that indirect way control the spacing of mounds of aeolian material around plants.[66] The fact that lag-gravel does not show notable concentration in the intermound areas may not be especially significant, as mounds of sand gathered by the wind around clumps of bushes on the Antelope Valley east of Palmdale have numerous pebbles on them where they were exposed by burrowing animals now living in holes under the bunches of shrubbery. (See Dalquest and Scheffer, Journ. Geology, Vol. 50, no. 1, p. 68, Jan.-Feb., 1942).

The beach ridges, described by A. J. Ellis in the paper already referred to (1919, p. 30), are quite conspicuous in the region north of the San Diego River (well shown on the topographic map of the La Jolla Quadrangle) where they have controlled the plan of subsequent canyon development, forcing Tecolote Canyon and smaller canyons east of La Jolla to assume a partial trellis drainage

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64 Kirk Bryan has expressed the opinion that the work of the wind is effective only where the rainfall is less than 10 inches per year (Amer. Journ. Sci., Ser. 5, Vol. 6, p. 306, 1923). The San Diego prairie mounds probably originated during a drier epoch preceding the Recent epoch.

65 Storie, R. E., and Carpenter, E. J., "Soil Survey of the El Cajon Area, California," U. S. Dept. Agric., Ser. 1930, no. 15, 1930. For a soil map of the northwestern part of San Diego County see the pamphlet and map by the same authors in "Soil Survey of the Oceanside Area, California," U. S. Dept. Agric., Ser. 1929, no. 11, 1929.

66 A letter dated October 29, 1937, from Professor Chas. F. Shaw, Division of Soil Technology, College of Agriculture, University of California, Berkeley, contains the following remarks on prairie mounds:

"I have long been interested in these mounds and have studied them from time to time incidental to studies of other soil features. It is my opinion that they are in most locations due to the wind drifting of soil and its accumulation around scattered plants. In the deserts where creosote bush is the dominant vegetative form the plants are usually spaced many feet apart. Each plant has an accumulation of soil about its base forming a more or less definite mound. This accumulation about the plants usually goes on until the intervening area has been stripped to the point where a desert pavement has accumulated that retards or prevents further wind drifting of the soil. The removal of the vegetation usually results in the dissipation of the mounds by further wind erosion but when such areas are first cleared the location of the mounds is very striking. Such mounds are builded not only where the drifted material is sand but also where it is as heavy as clay. It appears that this is the probable cause of such mound formation and I believe that it explains the occurrence of the mounds on most of the soils. On some of the soils, however, there is evidence that such wide-spaced vegtation may have served to prevent water erosion and the mounds may be remnants of an older surface. This is the case on some of the soils of the Redding series in the northern part of the state.

"In regions such as the San Diego coastal plain, the deep soils without heavy accumulations of clay in the subsoil or the presence of hardpan horizons will usually bear a rather complete vegetative cover. Where, however, we have soils with the heavy clay subsoils comparable to the Olivenhain or Las Flores, or the hardpans of the Redding, the moisture supply is insufficient for a complete perennial cover and the native vegetation is frequently rather widely-spaced stunted bushes or brush. It is quite probable that through this effect of soil profile development in rendering the subsoils less pervious and promoting a widely-spaced vegetation, there may be definite relations between the degree of soil development and the occurrence of the natural mounds. In regions of still lower rainfall it usually is associated with the competition for moisture."

Many years ago Dr. G. W. Barnes, first president of the San Diego Society of Natural History, wrote a paper on "The Hillocks or Mound Formations of San Diego, California" (Amer. Naturalist, Vol. 13, pp. 565-571, 3 figs., 1879). Barnes explained their formation as due to accumulation of wind-blown material around shrubs or clusters of shrubbery and rain wash of the surface between. However, some of the spaces between mounds are small enclosed basins which would not permit the escape of rain-washed material. The present authors believe that rain wash may have modified the mounds but that wind work has been the effective agent. A brief and still earlier account of prairie mounds occurring on the Pacific slope was given by Joseph LeConte (Proc. Calif. Acad. Sci., Vol. 5, pp. 219-220, Jan., 1874).

In a paper on the mounds of the Columbia Plateau, Waters and Flagler listed thirteen hypotheses to explain the origin of various types of prairie mounds and stated that, as a physiographic feature, they are polygenetic. See Waters, A. C., and Flagler, C. W., "Origin of the small mounds on the Columbia River Plateau," Amer. Journ. Sci., Ser. 5, Vol. 18, no. 105, pp. 209-224, 8 figs. in text, Sept., 1929.

The results of the work of C. C. Nikiforoff on the microrelief of the "hog wallow" areas of the Central Valley of California have recently been published by the U. S. Department of Agriculture. See "Hardpan and Microrelief in Certain Soil Complexes of California," U. S. Dept. Agric., Tech. Bull. 745, pp. 1-46, 18 figs., April, 1941.

pattern, so different from the almost perfect dendritic drainage pattern of the greater portion of the mesa. These ridges are generally composed of poorly stratified or unstratified sand of a reddish or brownish color, the color being due to weathering. The long ridge extending south from Torrey Pines Park appears to be an ancient beach ridge.[67] All of these ridges may be due to the accumulation of beach material just beyond the reach of the waves during a temporary halt of the regressing sea, or some of them may have been formed in the same manner as offshore bars.[68] They are interesting physiographic details of the San Diego region and are worthy of careful study.

The San Diego Mesa is but youthfully dissected by stream erosion, there being considerable interfluve area as yet uncut by running water. The northern portion, especially the mesa immediately adjacent to the south rim of Mission Valley and the Linda Vista Terrace north of it, is less dissected and hence more youthful than the southern portion, probably due partly to the harder rock in the Mission Valley region and partly to the closer spacing of the major stream valleys south of Las Choyas Valley. These valleys were cut by rivers with sources in the mountains far to the east and have histories which began before the initial stage of subaerial erosion on the relatively recently uplifted mesa. The Linda Vista Terrace is a fine example of the youthful stage of the normal cycle of stream erosion. It represents early youth, whereas the southern portions of the San Diego Mesa represent late youth. Throughout the San Diego Mesa region, with the exception of those portions modified by the beach ridges already mentioned, the streams have developed a dendritic drainage pattern due either to the uniform resistance or the horizontal attitude of the sedimentary strata of which the terrain is composed. Little tributary canyons have cut their way back into the mesa with little choice of direction, the many side-gullies pointing here and there like the smaller branches and twigs of a tree. In the eastern part of the mesa-lands some broad shallow valleys and low subdued hills occur which are strikingly different from the modern steep-sided V-shaped canyons cut by the present intermittent streams. These can be conveniently seen in the eastern part of the Otay Mesa but they occur elsewhere to the north. It is on the upper gentle slopes of these old valleys that the prairie mounds already described occur. While the authors did not have time to study these little subdued swales and valleys in detail, it seems possible that they were formed while the sea was cutting the terrace next below the Otay Terrace.[69] If such is the true explanation, then the short distance these early streams had to cut down to reach their base level accounts for their having widened their valleys to produce the low relief features usually associated with old age. In time the modern streams will dissect new V-shaped valleys within these old ones as headward erosion extends their courses farther and farther into the mesa.

Many of the canyons and valleys that cut the mesa have relatively steep sides with a sharp-angled shoulder at the top where valley side and mesa top meet (Plate 4, figure 2). This angular shoulder occurs where the mesa is capped by a thin but relatively hard and resistant conglomeratic sandstone discussed on another page as the Sweitzer formation. Wherever this formation occurs on the mesa it tends to produce steep-walled valleys, with angular shoulders. A peculiar feature of this hard sandstone layer, connected with its origin, is its unbroken extension from the top of the principal terrace, the San Diego Mesa, over the intervening slope to the next lower terrace. This can be seen at but few places (for example, in the Chula Vista region) but it must be considered as having an important bearing on its origin.

At several places on the mesa the surface layers of soil contain numerous concretionary pebbles averaging about the size of a pea, though some are a half-inch or more in diameter. These are brown in color and appear to be due to a concentration of a ferruginous cement. They are less well-

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67 This ridge has been partially sectioned by the new Torrey Pines Highway Grade. Another less conspicuous beach ridge occurs in Balboa Park from the Natural History Museum north. See the physiographic block diagram for occurrence of these and other features.

68 The origin and development of offshore bars has been described by D. W. Johnson in "Shore Processes and Shoreline Development" (John Wiley and Sons), 1919, p. 365 et seq.

69 This terrace is well-developed northeast of San Ysidro (which is 1.6 miles N.W. of Tijuana) at an elevation about 50 to 75 feet below the Otay Terrace. It was included in the Otay Terrace by Ellis (1919, pl. 6).

developed beneath the surface and Fairbanks[70] has noted that they decrease in size to a depth of about 2 feet below the surface where they cease entirely. These little nodules are quite abundant at some places, such as on the upper surface of parts of Point Loma and on the Linda Vista Terrace, sometimes forming a layer of loose spherules on the surface of the soil. They seem to be present only where Eocene rocks occur beneath the surface, for the authors failed to note any of them on the Pliocene mesa south of San Diego River.

The principal terrace, here called the San Diego Mesa, is probably represented by parts of the upper surface of Point Loma, though faulting has tilted some of the remnants. It is also represented by a less obvious surface about half-way up the southern and western slopes of Soledad Mountain, where it has likewise been been tilted by diastrophism.

The surface of San Diego Mesa has been developed almost entirely on Eocene and Pliocene rocks, the older rocks to the east probably having been too resistant to wave erosion to have been much reduced during the time the sea was at the proper elevation to truncate the Tertiaries. In the vicinity of La Mesa it is probable some terrace cutting (marine denudation) has truncated the pre-Eocene crystalline rocks, but the exposures are not good. Marcus Hanna mentioned remnants of wave-cut cliffs at the eastern margin of Linda Vista Mesa, but these were not studied by the present authors.

Younger Terraces

The western margin of the San Diego Mesa and the sides of some of the larger valleys contain well-preserved remnants of lower, younger terraces. In the San Diego Quadrangle, Ellis[71] has described and mapped five terraces including the Otay Terrace (= San Diego Mesa) but not including the coastal flats.[72] Beginning with the one next younger and just below the Otay Terrace, there are: the Avondale Terrace, with an elevation of from about 200 to 250 feet (Plate 5, figure 2); the Chula Vista Terrace,[73] 100 to 130 feet in elevation; the Nestor Terrace, 25 to 100 feet in elevation; and the Tia Juana Terrace, 20 to 50 feet in elevation. Aside from these named terraces and the Sub-Otay Terrace included in the Otay Terrace by Ellis, there are still other but smaller, poorly developed and imperfectly preserved intermediate terraces. Progressing south from Otay Valley these terraces occur at higher elevations and are separated by greater vertical intervals. As all the terraces, including the San Diego Mesa, are remnants of plains of marine denudation (and possibly to a very small extent, of marine deposition) and hence must each have been formed at approximately the same elevation during successive still-stands of the sea with respect to the land, it is apparent that uplift has been greater and more rapid as the Mexican Boundary is approached from the north. As it seems probable that most if not all of the terraces are probably not younger than middle Pleistocene, they testify to the lack of orogenic diastrophism in this region during a time when a large part of southern California north of the San Diegan district was undergoing diastrophism of considerable intensity.

These terraces warrant more intensive field work than the authors were able to devote to them. Some of them extend a considerable distance up the major river valleys. This latter fact has an interesting bearing on the ages of the valleys, and of course the older terraces in the mountains to the east also present evidence bearing upon the physiographic history of the region as a whole.

Older Terraces

In the foothills and mountains of crystalline rocks east of the coastal mesa region an older higher

[70] Fairbanks, H. W., Calif. State Mining Bureau, 11th Ann. Rept. State Mineralogist, p. 98, 1893. Marcus Hanna likewise notes these concretionary nodules and gives two figures of them. See Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, no. 7, pp. 218-219, pl. 23, figs. 1, 2, 1926.

[71] Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, pp. 25-28, pl. 6, 1919.

[72] Ellis did not recognize the terrace 50 to 75 feet below the Otay Terrace which is quite distinct in the region just northeast of San Ysidro. This terrace, which we here call the Sub-Otay Terrace, may have a genetic connection with the prairie mounds and earlier cycle stream valleys briefly discussed in this paper.

[73] Marcus Hanna calls the prominent terrace extending from La Jolla south to Pacific Beach at an elevation of from about 25 feet in the south to nearly 200 feet in the north, the La Jolla Terrace, but he believes it probably corresponds to the Chula Vista Terrace of Ellis. (M. Hanna, 1926, p. 194).

terrace can be readily seen. This was described by Ellis, and later by M. Hanna, as the Poway Terrace, due to its conspicuous development on the hilltops south of Poway Valley (in the northeastern part of La Jolla Quadrangle). The western part of this terrace is better developed in the northeastern portion of the La Jolla Quadrangle, north of the San Diego River, than it is farther south. East of the Linda Vista Mesa it can be seen at the tops of the hills, beginning at the west with an elevation of between 800 and 900 feet but sloping upward toward the east at the rate of about 50 feet per mile, so that elevations of 1,100 to 2,100 feet are attained in the El Cajon Quadrangle 5 to 20 miles to the east. It is probable that this higher older surface should be referred to as an old-land surface which had reached the old age stage in the cycle of subaerial erosion before the general post-Pliocene elevation[74] of the entire coast. This old-land surface is preserved on parts of the upper drainage basin of the San Diego River where recently cut canyons with V-shaped cross sections have only partly dissected the rolling upland.[75] This surface probably had many monadnock hills and peaks and thus was not a true peneplain although some of its present vertical irregularities may have been caused by later faulting.[76] In the paper on the water resources of western San Diego County referred to above, Ellis included a preliminary map of the County (1919, pl. 3) on which numerous faults and lines of topographic expression which suggest the presence of faults are delineated. Although the present authors were prevented by limitations of time from making a careful field study of the mountainous region, they believe that some faults will eventually be clearly established and that the northwestward trending fault bounding Warner's Ranch Valley (San Jose del Valle and Valle de San Jose land grants) and the Palomar Mountain mass on the southwest is quite definite. The fault on the southwest margin of this valley has been considered by Sauer to be an extension of the Elsinore fault which borders the northeastern front of the Santa Ana Mountains farther northwest.[77]

In parts of the region around Potrero and extending with interruptions far to the east of Campo and also for an unknown distance south into Lower California, Mexico, there is an old-land surface which is probably equivalent to the surface developed farther north. Sauer (1929, pp. 222, 248) has considered this "rude general level of the western flank of the highland, extending far into Lower California," a much dissected and warped Eocene marine terrace (p. 248). In arriving at this conclusion he may have been influenced by the possible genetic connection between the Poway conglomerate in the La Jolla Quadrangle, now considered to be of upper Eocene age, and the hilltop gravels which extend in an interrupted belt from near Witch Creek in a southwesterly direction towards the hills of Poway conglomerate east of Miramar. These hilltop gravels may or may not be the fluviatile phase of the Poway conglomerate; but if they are, they represent fragments of a formation which has, through the vagaries of long periods of erosion, escaped complete destruction. We do not believe they can be used to fix the date of the development of the old-land surface, since it seems more probable that subaerial erosion during Pliocene times is responsible for that feature of the topography. We know of no marine Eocene fossils occurring on this old-land surface and are disinclined to believe a marine transgression of the sea so far to the east occurred during Tertiary time.

That parts of this old-land surface were exposed to subaerial agents for a considerable period seems to be corroborated by very deep weathering. Water supply and reservoir site investigations

[74] In his paper on "The Post-Pliocene Diastrophism of the Coast of Southern California" (Univ. Calif. Bull. Dept. Geol., Vol. 1, no. 4, pp. 115-160, pls. 8, 9, 1893), Lawson first clearly called attention to the importance of Quaternary uplift along this portion of the Pacific coast.

[75] Merrill (Calif. State Mining Bureau, Biennial Rept., 1913-14, p. 8, 1914. Quoted by Ellis.) believed that faulting and folding was largely responsible for the irregularities of the topography of this upland area.

[76] Ellis (in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, p. 48, 1919) called attention to the plain-like slope of the highland area, and indicated a number of faults.

[77] Carl Sauer, in an important and interesting paper on "Land Forms in the Peninsular Range of California as Developed about Warner's Hot Springs and Mesa Grande" (Univ. Calif. Publ. Geography, Vol. 3, no. 4, pp. 199-290, pls. 21-41, 5 text figs., Dec., 1929), has described the physiography and explained the topographic development of a portion of northeastern San Diego County. A carefully prepared map is included which explains the author's interpretation of the kind of land surfaces represented and also the major faults. Sauer emphasizes the effect of denudation, *sensu stricto*, in producing concave land slopes, and stream erosion in producing convex surfaces. His analysis is based upon the somewhat deductive methods of Walther Penck (in that author's "Die Morphologische Analyse"), some of whose interpretations of land forms have been challenged by W. M. Davis (see "Piedmont Benchlands and Primärrümpfe," Bull. Geol. Soc. Amer., Vol. 43, pp. 399-440, 10 figs., June 30, 1932).

have shown that the granitic rock in some cases is weathered at least partially and is somewhat porous to a depth of 100 feet.[78]

SHORELINE FEATURES

The configuration of the shoreline of southern San Diego County is irregular due to differences in geologic structure and rock hardness. Wave erosion has etched out the resistant rock masses and the prograding or constructional work of the shoreline processes has tended to close up the embayments, resulting in rocky forelands between which are bays and sandy beaches. North of La Jolla the Tertiary Mesa composed of rocks of almost equal hardness has been evenly truncated by wave erosion, resulting in a long series of sea cliffs at the foot of which is a narrow beach. The land seems to be sinking slowly with respect to sea level, which permits the larger waves during storms to attack the base of the cliffs, oversteepening them and reducing them by landslides and other processes of cliff destruction. Observations of the lower southern portion of the cliffs at the Scripps Institution of Oceanography of the University of California, just north of La Jolla, show a rapid rate of retreat.[79] Along this part of the coast the marine cycle of shoreline development has reached a mature stage. No promontories remain and the coastline is a long gentle curve. About a mile south of the Scripps Institution the coast line projects out about a mile due to the resistant nature of the hard Cretaceous sandstones which outcrop there at sea level. Here the waves have sculptured the rock in a variable manner due partly to differences in induration of the successive beds of sedimentary rock, but probably more largely due to the jointing and concretionary nature of the sandstone. Caves, small arches and irregular stacks have been etched out by wave erosion. What appears to be a recently uplifted wave-cut terrace, a few feet above high tide, may be a small bench cut by exceptionally high waves during occasional storms. Southward from La Jolla the shoreline continues irregular for about three miles until Pacific Beach is reached. There the less resistant Eocene and Pliocene sediments have yielded more readily to wave attack and this feature, probably in combination with a local structural low, has produced a mature shoreline.

The material eroded from the shore south of La Jolla and more particularly from the embankment cut into the terrace upon which the community of Pacific Beach has been built, as well as the sediment brought to the shore by the small intermittent streams draining the western slope of Soledad Mountain, has been shifted southward by the coastwise currents, assisted by the waves, and deposited almost completely across the mouth of Mission Bay (formerly known as False Bay, and by the early Spaniards as Puerto Falso), resulting in a long sand spit with a narrow tidal opening at the south. This is now known as Mission Beach. Underlying the sandy surface of this sand spit, at about mean sea level, and below, numerous cobbles occur which have been encountered in test pits dug by the City Engineer of San Diego.

Mission Bay seems to have had a structural origin. It may be the submerged southern downwarped part of the Soledad Mountain block. If this is the true explanation, hidden faults probably exist near its eastern and southern margins. A fault bordering the east shore of Mission Bay is suggested by the difference in altitude of Eocene beds on opposite sides of Rose Canyon, the presence of a small spring[80] near the bay shore between Atwood and Morena, 2.55 miles north of the San Diego River dike on U. S. Highway 101 (Pacific Boulevard),[81] and a tilted block of Eocene strata which formerly

[78] Professor C. F. Tolman, verbal communication, 1935.

[79] T. W. Vaughan (Science, New Ser., Vol. 75, no. 1939, p. 250, Feb. 26, 1932) has recorded a 20 foot recession of a cliff 21 feet high in 12 years, and lesser recessions of higher cliffs.

Lakes discussed details of erosion of the cliffs along the seaside at La Jolla. (Lakes, Arthur, "Geologizing by the Seaside. Illustrations of Geologic Phenomena related to Mining as shown in the Sea Cliffs and Caves at La Jolla, near San Diego, California," Mines and Minerals, Vol. 23, no. 12, pp. 543-545, 6 figs., July, 1903. — "The Sea and Mining. Illustrations Shown at Sea Coast of Manner of Making and Destruction of Rocks by Action of Shellfish and Erosion," Mines and Minerals, Vol. 24, no. 1, pp. 12-14, 6 figs., Aug., 1903).

[80] H. W. Fairbanks mentioned a large tufa deposit on the "southern" shore of False Bay. See 11th Ann. Rept. Calif. State Mineralogist, p. 97, 1893. A letter from the late Frank Stephens, dated Aug. 27, 1937, states that in his opinion the spring mentioned by Fairbanks is the one on the *east* shore of Mission Bay.

[81] This spring, which is now a mere seep, is 2,376 feet north along U. S. Highway 101 from a point where joined by Jellett Street. This is a little north of where Edison Street, if projected, would intersect the highway. Tufaceous material is exposed in the road embankment for about 100 yards near the spring.

existed north of San Diego River north of Old Town.[82] A possible southern (east-west) fault is entirely hypothetical but appears to be strongly suggested by the structural relations in this region. The chief characteristics of Mission Bay at the present time are its very shallow depth of water, and the large delta of the San Diego River which threatens to encroach farther and farther upon the remainder of the Bay.[83] It seems possible that *Salicornia* sp. and *Spartina leiantha* Bentham and other salt and brackish marsh plants may play some part in reducing the area of occasionally submerged portions of tidal flats in this region. The *Spartina,* particularly, may be effective in accelerating deposition since it grows largely below mean high water[84] and tends by its presence to reduce the velocity of currents transporting sediment during times of flood or storm. The *Salicornia,* on the other hand, grows mostly above mean high water, and is only partly inundated by extreme high tide. It tends to prevent erosion, however, and gradually adds to the sedimentary layer by the accumulation of a "peaty" material composed of its dead stalks and roots.

The small intermittent streams which occasionally flow from Tecolote Valley and Rose Canyon have built small deltas which likewise reduce the volume and area of the bay. Projecting south into the bay from Pacific Beach is a broad point which is an extension of the La Jolla Terrace. This is known as Bay Point or Crown Point. Its surface is largely covered with windblown sand which is now weathered a light yellowish brown. It may have been built in somewhat the same manner as the Mission Beach sand spit. Below the covering of aeolian sand, Crown Point is composed of late Pleistocene fossiliferous cross-bedded sands and silts, and is either an ancient sand spit or the wave-built portion of the La Jolla Terrace (Plate 14). When the sea submerged Crown Point, the coastal currents must have swept over what is now the low ground between Mission Bay and San Diego Bay, isolating Point Loma as an island.

All of the low flat land between Old Town and the northeast margin of Point Loma is a delta deposit of the San Diego River.[85] This river and its distributaries occupied many different positions on the growing delta. In 1849 it was flowing into San Diego Bay, according to the manuscript map of Lieutenant Cave J. Couts of the First Dragoons, U. S. Army.[86] The San Diego River is also depicted as flowing into San Diego Bay in the "Official Map of the Pueblo Lands of San Diego" compiled by Charles H. Poole, U. S. Deputy Surveyor, in 1856, and in the U. S. Coast Survey Map

[82] This tilted block had an east-west strike and dips 45° south. This little hill has been completely removed by grading operations.

[83] A relatively short time ago this bay must have had a considerably greater depth of water, for Sebastian Vizcaino referred to it as a good harbor, and Derby in 1853 (Senate Exec. Doc. 1, 33rd Congress, 1st Session, pt. 3, p. 111, 1853) stated: "Before 1810 the False bay was sufficiently deep to admit of the ingress of vessels of very considerable size; at present it is filled with shoals and sand bars, and has hardly sufficient water at low tide for an ordinary sail-boat."

[84] According to the investigations of Dr. Ira L. Wiggins of Stanford University, at the Mission Bay Causeway *Spartina* ranges from 1.43 feet to 3.92 feet above Mean Lower Low Water in Mission Bay. The lower limit of *Salicornia* here is 3.64 feet above Mean Lower Low Water. Mean High Tide in Mission Bay is 3.70 feet above Mean Lower Low Water. The latter datum in Mission Bay is 1.21 feet above that of La Playa in San Diego Bay. The lower limit of both *Distichlis* and *Frankenia,* when present, is always just above mean high water. According to Dr. Wiggins, these salt marsh plants have a slightly different vertical range at other localities. For example, at National City on San Diego Bay, where Mean High Water is 5.20 feet above Mean Lower Low Water at La Playa, *Spartina* ranges from 3.46 to 5.93 feet, *Salicornia* has its lower limit at 4.65 feet, *Distichlis* lives as low as 5.56 feet and *Frankenia* has a lower limit at 5.66 feet.

[85] G. H. Derby, Lieutenant of Topographical Engineers (Senate Exec. Doc. 1, 33rd Congress, 1st Session, pt. 3, 1853, p. 111) in 1853 made the following statement in regard to this delta plain: "Judging from the topography, it may be supposed that the False Bay and San Diego harbor were originally one sheet of water, the sandy plain now separating them having been formed by the deposits of sand from the river; if this was the case, it was before the settlement of this part of the country, as none of the old Spanish residents remember, or have any tradition of such a thing. I have, however, been told of the existence in San Francisco of an old Spanish chart on which the bays are thus represented." See also J. Kearney, pp. 257-262, in same document.

[86] Now in possession of Mr. Cave Johnson Couts of the Guajome Rancho, near Oceanside, San Diego County. This map, dated April 28th and 29th, 1849, is one of several showing the route traversed by Lieutenant Couts' Command during this period.

See also report of G. H. Derby (Senate Exec. Doc. 1, 33rd Congress, 1st Session, pt. 3, 1853, p. 110) in which he made the following statement regarding the former positions of the mouth of the San Diego River: "At the time of the first establishment of the Mission of San Diego, and the 'Presidio,' or military post, this plain, and in fact the whole valley for six miles above, was covered with a dense forest of sycamore, willow, and cotton-wood, with an undergrowth of various kinds of shrubbery, among which the wild grape was most abundant. At this time the river ran through the most northerly part of the plain, skirting the hills represented on the plan, and emptied into False bay. This course it continued until 1811, when, by the continued deposit of sand, its bed was so much elevated that it altered its channel to the southwest, still however emptying into False bay, until 1825, when a great freshet occurring it overflowed its banks, destroying many gardens and much property, and formed a new channel discharging into the harbor of San Diego. From the continued accumulation of sand its course has somewhat fluctuated but has never been essentially altered since that period."

of this region dated 1859. A portion of this latter map has been reproduced in our Plate 1. It shows an older channel of the San Diego River leading into False Bay. The high rate of deposition from the river threatened to destroy San Diego Bay as a harbor and the Federal Government diverted San Diego River into False Bay (now called Mission Bay) in 1853 by the construction of a dike.

A levee or embankment of earth was built from a point near Old Town to a point on the opposite highland on the north end of Point Loma, a distance of about 3,570 feet. This was built under the direction of Lieutenant George H. Derby,[87] U. S. Topographical Engineers. Work began[88] on September 19, 1853, and apparently was completed[89] on November 20, 1853. Later on that same year heavy rains caused the river waters to wash out a part of the levee and the river resumed its course into San Diego Bay.[90] It continued in this course until 1876[91] when an adequate earthen embankment was constructed which has permanently forced the river into False Bay (see Plate 15, figure 1).

Since the completion of the levee of 1876 a considerable volume of sediment has been added to the San Diego River delta in Mission Bay. In 1937 the State of California employed a civil engineer, Norman O. Glover, to resurvey the profiles surveyed in the delta region by Lieutenant John H. Weeden, U. S. Army Engineers, in 1875. Weeden's base line was reestablished and his elevations adjusted to coincidence with the new levels at the summits of two low knolls of Quaternary non-marine reddish sandstone in the delta flat north of the west end of the present levee. A comparison of these profiles indicates no significant change in elevation of the flats south of the levee, but north of the levee much of the surface is now from 2 to 4 feet above that of 1875.[92] A brief field study of a portion of the delta of the San Diego River north of the levee has shown that a deposit of light gray medium-grained sand, containing abundant brown and yellow weathered biotite mica, about 2 to 4 feet thick, overlies a brown sandy or silty clay. The upper layer of gray sand may represent the material deposited by

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87 For an account of Derby's work in California see "The Topographical Reports of Lieutenant George H. Derby," Introduction, by Francis P. Farquhar, Quarterly of the Calif. Hist. Soc., Vol. 11, no. 2, pp. 99-102, June, 1932. Reprints of Derby's reports occur in no. 2, pp. 102-123, 2 maps, June, 1932; no. 3, pp. 247-265, 1 map, Sept., 1932; no. 4, pp. 365-382, 1 map, 6 sketches, Dec., 1932. The separates containing these reports issued by the Calif. Hist. Soc., Spec. Publ. 6, 1933, contain additional information not included in the complete volume. See especially pp. 65-71 for information regarding Derby's work at San Diego.

88 See The San Diego Herald, Vol. 3, no. 33, p. 3, col. 5, Sept. 24, 1853. "This work was commenced by Lieut. Derby, U. S. Corps of Topographical Engineers on Monday last [Sept. 19, 1853]. His orders are to excavate the former channel of the river discharging into False Bay and to build a levee or embankment of earth from a point near the Old Town to a point on the opposite high land (distance 1,190 yards) intersected by the Playa road to counteract the action of subsequent freshets. Sixty laborers with carts, wheelbarrows, etc., are to be put on the work at once" . . .

89 Letter from Lieut. George H. Derby to Col. J. J. Abert, Chief Topgl. Engineers, San Diego, Nov. 20, 1853. "I have the honor to inform you that the work on the San Diego River was this day completed, in the manner described in my report of the 15th Oct. ult." (Letter on file in the archives of the U. S. Army Engineers, War Department, Washington, D. C.).

90 See the San Diego Herald, Vol. 5, no. 1, p. 2, col. 4, April 21, 1855. "We mentioned some time ago that a part of the dam which Lt. Derby, U. S. Top. Eng., erected, for the improvement of San Diego harbor had given away under the pressure of water caused by the first heavy rains, and that the river, which had been turned into False Bay, was running in its original channel. In four years we have never known the water to be so high as this season. The rain which fell during the early part of the week has had the effect to considerably widen the breach in the dam and if something is not done before the next rainy season to repair the damage the amount of the outlay which has already been made, will be worse than thrown away."

91 On June 5, 1876, ground was broken for the new levee which was completed on Nov. 6 of the same year. Ann. Rept. Chief of Engineers [U. S. Army] for 1876, pt. 1 (44th Congress, 2nd Session, House of Representatives Ex. Doc. 1, Vol. 2, pt. 2, 1876), p. 114; Ann. Rept. Chief of Engineers for 1877, pt. 2 (45th Congress, 2nd Session, House of Representatives Ex. Doc. 1, Vol. 2, pt. 2, 1877), Ap. II, p. 998.

Additional information regarding the dike can be found in the Ann. Rept. Chief of Engineers for 1874, pt. 1, p. 119, pt. 2, Ap. AA3, pp. 372-375; 1875, pt. 2, Ap. FF2, pp. 723-724; 1878, pt. 1, p. 136, pt. 2, Ap. II1, pp. 1301-1302. According to accounts the north side of the levee was faced with a heavy stone wall which rested on a stone foundation five feet deep. The levee was over 7,000 feet long, 15 feet wide at the top, 40 feet wide at the base, and 5 feet high. See also the San Diego Union, Sept. 11, 1876.

The earth used in the construction of the dike came in part from the cliff at the northeastern end of Point Loma near the present intersection of Mission Bay Causeway and West Point Loma Boulevard and in part from the site of the fort on the point of the hill below the old Presidio at Old Town. According to a local historian: "Nothing whatever of the site [of the old fort] now remains, the earth forming the point of the hill having been hauled away and used by the government engineers in making the embankment for turning the San Diego river, in 1877. Some of this earth was also used for grading the county road across the valley from the end of the Old Town bridge, in later years. These excavations also took large quantities of earth from the north side of the hill, the extent being measured by the widening of the road from a narrow track to its present width." (See Black, Samuel F., "San Diego County, California. A Record of Settlement, Organization, Progress and Achievement." The S. J. Clarke Publishing Co., Chicago, p. 82, 1913).

92 See testimony, and plaintiff's exhibits Nos. 3 and 9, People of the State of California vs. Charles E. Arnold et al. No. 84864 Superior Court San Diego County, Hon. Chas. C. Haines, Judge, 1938.

the San Diego River during the flood discharges since 1875. At one locality this sand contained a specimen of *Physa,* a fresh water shell, and at another, a piece of broken Indian pottery.

Like most streams in this region the San Diego River is characterized by infrequent floods[93] during which a large amount of sediment is carried to its delta. These occasional floods have been the effective agent in building the delta because the river is generally dry during late summer and autumn and may be dry for an entire year or more. The construction of the El Capitan Dam[94] on the San Diego River about seven miles above Lakeside in 1935 may reduce the frequency and violence of future floods and delay the growth of the delta in Mission Bay from now on.

In addition to the growth of the delta of the San Diego River in Mission Bay, some shoals and small islands have been formed in that shallow body of water by the action of tidal currents and waves. The light areas shown on Plate 17 at the western extremity of the deltaic region (extreme right middle part of view) are small dune ridges, two of which reach an elevation of about 10 feet above Mean Lower Low Water. The sweep of the currents in and out of the narrow entrance channel of Mission Bay tends to deposit a submarine bar off the ocean end of the entrance and tidal inlet delta shoals within. Wherever the incoming currents spread over a greater cross-sectional area their velocity diminishes and consequently their power to transport sediment decreases. The first rapid decrease in velocity occurs just within the entrance to the bay and there a prominent shoal occurs which is exposed at low tide. It is an incipient tidal inlet delta island which has nearly reached the plane of Mean High Water. As the incoming currents flow northward east of the Mission Beach spit they fan out over a larger area and deposit some of their load of sediment across the bay floor west of the causeway and southwest of the south end of Crown Point. The shoaling here has been sufficient to permit a luxuriant growth of *Spartina.* Some of the *Spartina*-covered shoal areas are shown to the right of Crown Point on Plate 17. Other *Spartina*-covered shoals east of the causeway seem to indicate further spreading out of the currents. The reduction of the tidal prism in Mission Bay has undoubtedly slowed up this island-forming process. At a previous time, when the river delta was smaller and the volume of tidal water was larger, the currents were more effective and tidal current island formation took place on a larger scale. It seems highly probable that a portion of the deltaic area west of the causeway was originally formed as a tidal inlet delta island. Field studies by Grant and the mechanical analysis of sediment samples tend to confirm this theory. The formation of such islands has been recently described by Lucke.[95]

Point Loma is a long promontory extending from the tidal flats of Mission Bay for a distance of over six miles to the south. It land-locks the western portion of San Diego Bay. Its northern part is nearly three miles wide but it narrows toward the south to a little over one-half mile near the extreme point. Its truncated top averages just over 300 feet in elevation except in the northern broader part which is somewhat lower. The terraced top may have originated at the same time as the San Diego Mesa, and its isolation may be due to relatively recent (possibly late Pleistocene) foundering of the formerly continuous land on one or more sides.[96] Parts of its eastern and western shoreline are bordered by a narrow terrace with an elevation up to 25 or more feet. Stephens considered this terrace as well as the La Jolla Terrace (the Nestor Terrace of Ellis) the result of a submergence following the great Pleistocene emergence. Point Loma does not exhibit the well-defined intermediate terraces which characterize the western margin of parts of the San Diego Mesa. The western shoreline of Point Loma is irregular

93 According to Mr. H. B. Lynch, consulting hydraulic engineer of Los Angeles, floods occurred in the San Diego River in the following years: 1811; 1825 (San Diego River broke into San Diego Bay); 1839-40; 1855; 1857; 1862; 1873-74; February, 1884; December, 1889; January, 1916; February, 1927.

Mr. Fred D. Pyle, Hydraulic engineer for the City of San Diego, states in a letter dated November 24, 1939: "Two years ago in studying the preliminary flood control problems of the San Diego River, the Army Engineers reported floods of maximum intensity in the following order: 1862, 1916, 1825, 1927. The 1883-84 season produced by far the most water of any year of historical times but did not produce maximum intensity of floods comparable to those mentioned above."

Early floods in the San Diego River are mentioned by several historians. See Gunn, Douglas, "Picturesque San Diego, with Historical and Descriptive Notes" (Knight and Leonard Co., Chicago), 1887, p. 25.

94 This dam, which began to impound water Jan. 8, 1935, has a capacity of 38,000,000 gallons.

95 Lucke, J. B., "A Study of Barnegat Inlet, New Jersey, and Related Shoreline Phenomena," Shore and Beach, Vol. 2, no. 2, pp. 5-54, 1934. — "A Theory of Evolution of Lagoon Deposits on Shorelines of Emergence," Journ. Geol., Vol. 42, no. 6, pp. 561-584, 11 text figs., Aug.-Sept., 1934.

96 Fairbanks mentions a "strong sulphur spring exposed at low tide" at the end of Point Loma. We did not locate this spring during our field work. It may have some bearing on faulting. See 11th Ann. Rept. Calif. State Mineralogist, p. 97, 1893.

in detail due to the hard Cretaceous rocks exposed at sea level.

San Diego Bay is an elongate, irregular crescentic, land-locked body of water connected with the ocean by a narrow tidal channel on the east side of Point Loma. The entire southern and southwestern shore of the bay consists of North Island and Coronado Island and the sand spit which connects them with each other and both of them to the mainland at the south. North Island and Coronado Island may be remnants of the Nestor Terrace, as supposed by Ellis,[97] but their connection to the mainland is due to a long crescentic sand spit which appears to have been constructed by the northward shifting of material brought to the shore by the Tia Juana River which reaches the sea near the Mexican Boundary. Spanish Bight is a small, shallow re-entrant of San Diego Bay between North Island and Coronado.[98]

Except where occasional dredging has maintained a deep-water navigable channel, San Diego Bay is relatively shallow. Tidal scour at the entrance has been assisted by a jetty. This jetty, known as the Zuninga or San Diego Jetty, may have had some important effect upon the currents and wave action along the ocean shore of Coronado and North Island. Shortly after it was built, large waves during a storm in the spring of 1905 eroded away a large part of Ocean Boulevard west of Hotel del Coronado. In regard to the construction of this jetty, Lieut. Col. R. A. Wheeler, Corps of Engineers, U. S. Army, states in a letter to us dated Washington, D. C., July 29, 1938: "The river and harbor act approved September 19, 1890, authorized the construction of a jetty 7,500 feet long on Zuninga Shoal with a view to securing a depth of 26 feet on the outer bar. The jetty, of rubble stone construction, was built to the height of extreme high water and was completed in 1904. The annual report of the Chief of Engineers for 1937 states that the jetty has deteriorated to the extent of about 75,000 tons of stone displaced." According to a report by Colonel Chas. T. Leeds to Mr. M. W. Reed, City Manager of the City of Coronado, the Zuninga Jetty was begun in October, 1893, and its construction continued intermittently until its completion in July, 1904. In a report by Mr. D. E. Hughes, Assistant Engineer, to Lieut. C. T. Leeds, dated April 26, 1910, it is stated that following the extension of the Zuninga Jetty in 1900, erosion occurred just west of Spanish Bight, so that the railroad tracks supplying material to build Battery Meed (just northwest of the root of the jetty) had to be moved in 1901. Erosion began again during the next extension of the jetty in 1903 to 1904, this time farther east along Spanish Bight and eastward.

A small stone jetty or breakwater was built just southeast of the Hotel del Coronado in 1897 and 1898 to protect the hotel from wave erosion. It was repaired and extended at a later date.[99] Although the prevailing direction of drifting of beach material along the Silver Strand southeast of the hotel property appears to be toward the northwest,[100] the beach adjacent to the hotel property came under the influence of the Zuninga Jetty when it was extended to its full length. According to a report dated January 8, 1909, by Mr. Andrew Ervast, then Engineer of the Coronado Beach Com-

[97] Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, pl. 6, 1919.

[98] Neither of these is now a true island because they form a part of the Coronado peninsula.

[99] Data from report by Col. Chas. T. Leeds to Mr. M. W. Reed, City Manager of Coronado. In addition to this breakwater, "About 1900 there was constructed, a short distance east of the 'hotel breakwater,' and close to the bath house, a small rock groin." By 1931 the rocks of this structure were almost completely buried in beach sand. (From rept. of Col. C. T. Leeds). In Sept., 1940, some of these rocks barely protruded above the sand.

[100] Foreshore beach samples collected on Aug. 23 and 24, 1940, from the Zuninga Jetty to the Mexican Boundary showed, in general, a gradual increase in median grain size of sand particles from North Island to the mouth of the Tia Juana River. The partly decomposed golden-brown biotite flakes so abundant on the foreshore of North Island and Coronado Beach are much less common further southeast. The foreshore slope of the beach is also much steeper in the south than on North Island or Coronado Beach. The slope of the foreshore appears to be at least in part a function of grain size, and the latter is controlled by the violence of wave action. Back of the beach on North Island and back of the beach along the Silver Strand and southward to the Mexican Boundary there are small sand dunes which testify to the action of on-shore winds in removing sand from the beach. No notable accumulation of pebbles or cobbles was seen in this sand dune area except south of the mouth of the Tia Juana River, where a large number of flattish pebbles 1 to 4 inches long lie mostly buried in the sand of the eastern part of the small dunes, (see Plate 5, figure 1). Dr. Cordell Durrell, who examined these pebbles for us, determined them as dominantly hard metamorphosed andesitic and rhyolitic porphyries with occasional specimens of lime silicate hornfels. They are probably of pre-Cretaceous origin. They probably represent a local accumulation of material eroded from the bluffs of the Pliocene rocks back of the beach just south of the International Boundary. That they do not represent a concentration of gravel from the Tia Juana Valley alluvium is apparent from the fact that specimens of hornblende-rich andesite, basalt, and other non-metamorphics are absent in the beach deposits, but are common in gravel lenses in the valley fill encountered in well cores a mile or two east of the beach. The pebbles in the valley fill are, in general, less well rounded than those near the beach.

pany and City Engineer of Coronado, local news items in the San Diego Union,[101] and data assembled by Col. Chas. T. Leeds, storms in January, 1905, (during flood tide on about the 4th and 20th of the month), on February 5th, 1905, and again during the middle of March, 1905, caused serious wave erosion along the Hotel del Coronado grounds and Ocean Boulevard just west thereof. Mr. Ervast's report mentions that along Ocean Boulevard a total width of 110 feet of land was removed by the waves, leaving a vertical bank 6 to 18 feet high. To prevent further erosion such as was caused by these storms, a seawall of quarry-run stone 5,200 feet long was built from the hotel westward along Ocean Boulevard between August, 1906, and October, 1907. It was repaired in 1912 and 1928.

The mainland shore of San Diego Bay is mostly salt marshes and tidal flats, except where the presence of the Nestor Terrace produces a small bluff just above high tide line. The small intermittent streams from Las Choyas, Sweetwater and Otay Valleys have constructed small marshy deltas.

Tia Juana[102] River, which flows into the ocean south of San Diego Bay, has not produced a delta because the waves and currents have been effective in removing the sediment as fast as it is brought within their reach.[103] However, the river-transported silt has caused a gentle projection of the coast, but present day sinking of the land has resulted in salt marshes and small tidal lagoons behind the spit-like sandy beaches which are witnesses of the greater strength of the waves and long-shore currents. The northward shift of the sediments is due to either an eddy on the lee or southeast side of Point Loma or to the occasional southwest storm winds whose effect, though of short duration, is greater than the prevailing but gentle west and northwest breezes.

The Nestor Terrace is continuous from the foot of the San Diego Mesa (called Otay Mesa on the topographic map) westward to the beach north of the mouth of the Tia Juana River, except for a little swale extending from the Tia Juana Valley northwesterly to the southern end of San Diego Bay. This small drainage depression crosses the road just west of Nestor and Palm City. It appears to represent a channel eroded by occasional overflow waters from former great floods in the Tia Juana Valley, but it does not indicate a former course of the Tia Juana River into San Diego Bay. The Otay River and the Sweetwater River, which enter the bay, may have had some part in eroding a valley which is now submerged and represented by the southern part of San Diego Bay.

THE PENINSULAR MOUNTAINS

The mountains of San Diego County appear, in general, to be a series of irregularly disposed peaks and ridges transected by numerous stream valleys. If one could imagine all the valleys filled up to their margins, then one would see an old-land surface bearing numerous projecting hills and peaks but all with a gradual ascent from the foothills on the west to the highest summits on the east. This hypothetical picture, however, would not be an ideal example of the old age stage in the normal cycle of stream erosion, for faulting has entered the scene and broken up the terrain so that some blocks have been elevated more than others. Thus the general elevation is not uniform throughout a gradually eastward ascending surface. The Palomar Mountain mass, Volcan Mountain, the Laguna Mountains, and others, appear to have derived their topographic prominence at least partly by faults. These faults are in most cases hard to locate in this region of crystalline rocks except by their topographic expression or zones of brecciation. It appears that the supposed presence of some faults which

[101] See, for example, San Diego Union, Feb. 4, 1905, pp. 1, 3; Feb. 5, 1905, p. 5; Feb. 7, 1905, p. 6.

[102] It should be mentioned that the spelling "Tia Juana" is that of American usage as shown on the topographic map of the San Diego Quadrangle, whereas the official Mexican spelling is "Tijuana."

[103] The discharge of sediment by the Tia Juana River will no doubt be decreased in the future, due to the construction of the Rodriquez Dam on this river about 11 miles (17 kilometers) east of the municipality of Tijuana. This dam, which has a capacity of 137,000,000 cubic meters and was completed in February, 1937, was constructed for the storage and diversion of water for irrigating about 5,000 acres in Tijuana Valley in Mexico and for domestic use of the 10,000 inhabitants of Tijuana. See Williams, C. P., "Foundation Treatment at Rodriquez Dam," Proc. Amer. Soc. Civil Eng., Vol. 58, no. 8, pp. 1375-1385, Oct., 1932 — Trans. Amer. Soc. Civil Eng., Vol. 99, paper no. 1863, (Proc. Vol. 60, no. 8, pt. 2) pp. 295-313, 9 figs., 1934. The total drainage area of the Tia Juana River is about 1,668 square miles, of which 939 square miles are above Rodriquez Dam. Since there are about 250 square miles of drainage above Barrett Dam on Cottonwood Creek, a tributary in the United States, the lower Tia Juana River now has a total of only 479 square miles of uncontrolled drainage area below the dams. See 71st Congress, 2nd Session, House Doc. 359, "Report of American Section of International Water Commission, United States and Mexico," April 21, 1930, Ap. 1, p. 79, and map facing p. 84.

have been reported in this region is based upon slight evidence. The trend of most of the important faults is roughly northwest and southeast, thus partaking of the general directional pattern of well-known faults farther north, such as the Elsinore fault, the San Jacinto fault, and others.

It can hardly be said yet with absolute certainty from our limited knowledge of this country that the gently rolling surface on the higher parts of the Palomar Mountains, the upland meadows and subdued hills on the summit area of the Laguna Mountains, and other similar features, are upfaulted correlatives of the less elevated but more extensive general old-land surface of the region as a whole. The existence of these subdued topographic forms so far from the coast, so high in elevation and not yet maturely dissected by the narrow, deep canyoned streams which are actively eroding their courses, suggests a recent rejuvenation of the entire region with the initiation of a new erosion cycle which has now reached only the stage of late youth.

This mountainous area is terminated on the east by a steep descent to the low depressed area of the Colorado Desert. It seems highly probable that this eastern margin of the Peninsular Range is defined by faults, but the irregular margin of the mountains, with numerous projecting ridges extending far eastward into the desert, suggests a complex series of faults rather than one fault or one fault zone, which would tend to produce a scarp of a more nearly linear character.

STREAM VALLEYS AND DRAINAGE

Coastal Mesa Region

The larger valleys which have been cut through the San Diego Mesa, such as Mission Valley, Sweetwater Valley, Otay Valley and Tia Juana Valley, are characterized by flat sandy or silty bottoms and abrupt side slopes, the river channels being three hundred feet or more below the upper surface of the mesa. All these major valleys have been eroded into the relatively soft Tertiary sediments of the mesa by rivers whose headwaters are far to the east in the mountainous region where the annual rainfall is much greater than that of the coastal area. Otay Valley, unlike the others mentioned, has a broadly rounded bottom which may be due to its being a younger valley, as explained by Ellis. All these valleys owe their flat floors to aggradation, the valley fill being possibly as much as two hundred feet deep in some cases.[104] The depth of the river alluvium in the Tia Juana Valley has been determined by a geophysical survey made in connection with underground water problems. About 3,200 feet north of Monument School (which is just east of the mouth of Smallcomb's or Smugglers' Canyon) the bottom of the valley fill is at approximately 110 feet below mean sea level. As the surface there is just over 20 feet above mean sea level, the valley fill is over 130 feet thick. Along a north-south geophysical traverse about 6,200 feet west of the Monument School the maximum depth of the bottom of the valley fill is at approximately 120 feet below mean sea level. This is about 500 feet north of the location of the Holderness Well mentioned in another part of this paper. It is of interest to note here that the ground water table in the Tia Juana Valley (except within the temporary depression cones surrounding actively pumping wells) is sufficiently above sea level to prohibit the influx of sea water beneath the fresh water under the principle of Ghyben and Herzberg.[105]

During the time of greatest emergence in the Pleistocene the major streams cut deeply into the Tertiary strata but have since aggraded their lower courses. The minor valleys and the tributaries of the larger ones just mentioned are characterized by steep-sided V-shaped cross-sections. Except where the ancient beach ridges north of Mission Valley have controlled the initial post-emergent run-off

[104] Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, p. 33, 1919.

[105] Badon Ghyben, W., "Nota in verband met de Voergenomen Put boring Nabij Amsterdam," Tijdschr. Kon. Inst. Ing., 1888-89, p. 21, The Hague, 1889; Herzberg, Baurat, "Die Wasserversorgung einiger Nordseebäder," Jour. Gasbeleuchtung und Wasserversorgung, Jahrg. 44, Munich, 1901. Well explained by John S. Brown, "A study of coastal ground water," U. S. Geol. Surv., Water Supply Paper 537, pp. 16-18, 1925. See also, Tolman, C. F., "Ground Water," (McGraw-Hill Book Co., New York, 1937), pp. 246-247; Stearns, H. T., and Vaksvik, K. N., "Geology and Ground-Water Resources of the Island of Oahu, Hawaii," Territory of Hawaii, Dept. Public Lands, Division of Hydrography, Bull. 1, pp. 237-238, May, 1935.

The Ghyben-Herzberg principle is strictly true only in cases of hydrostatic equilibrium, that is, when the fresh water is at a constant potential. For low potential gradients the formula expressed in the Ghyben-Herzberg theory is approximately correct, but where ground water near a pumping well or near the sea has considerable motion the dynamic equations developed by Professor M. King Hubbert should be used. In the latter case the fresh water-sea water contact under the land surface is lower than the value given by the static equilibrium formula. See Hubbert, M. King, "The Theory of Ground-Water Motion," Journ. Geol., Vol. 48, no. 8, part 1, Nov.-Dec., 1940, especially pp. 870-873, 924-926.

and thus deflected the streams, the drainage pattern is distinctly dendritic. The steep valley sides, often with little talus accumulation at the base, are more or less characteristic of regions of small annual rainfall, with occasional sporadic floods.

Peninsular Mountains

East of the San Diego Mesa the streams have cut steep-walled valleys into the crystalline rocks of the mountainous region which characterizes the central and eastern parts of San Diego County. The San Diego River and Sweetwater River flow for many miles through deep, steep-sided valleys, with the river beds often 500 or more feet below the old-land surface described on a preceding page. This is well shown in the view of a canyon, cut by a tributary of the San Diego River, illustrated in Plate 4, figure 1. These valleys give the appearance of being entrenched through a recent revival of erosion. San Diego River, the largest river in southern San Diego County, has a flat floor or flood plain for some miles above Lakeside, but the steep valley sides with the more or less angular shoulder at the rim of the old-land surface, and the V-shaped tributary valleys, are characteristics of youth in the present cycle of erosion. Occasional broad valleys exist in parts of the drainage basins of these rivers, such as Potrero Valley, Morena Valley, Pine Valley, Descanso Valley, and others. They are probably due to variation in rock resistance or to structural causes not determined by us. Some of the upper tributaries of San Diego and Sweetwater Rivers have their sources in swampy or damp near-summit meadows.

The drainage of the mountains is nearly all westward, the divide between streams flowing to the Pacific and those flowing to the desert being very close to the eastern margin of the mountains. The drainage pattern is very irregular, which appears to be due to structural causes, in some instances possibly due to faulting; but this problem requires much study. Ellis has indicated the probable existence of a number of faults which have influenced the drainage, and Sauer has described some valleys in the Mesa Grande region which are probably genetically connected with faults.

PHYSIOGRAPHIC HISTORY

An adequate treatment of the geomorphogeny of that portion of San Diego which is briefly described, for the most part in an empirical manner, in the present paper, would require a long and intensive field study which the present authors have not been able to pursue. It is hoped that the brief outline of a probable series of more important events given here will be taken as a stimulus to an intensive study by others and not as a final interpretation or explanation of this very interesting and physiographically complex region. Gale[106] has presented some ideas on the origin of the San Diego Mesa, based largely on field data furnished by Grant.

The San Diego Mesa, composed of gently inclined Eocene and Pliocene sediments, is a plain of marine denudation, the Tertiary strata being distinctly truncated. During the deposition of the Pliocene sediments the sea must have had a position far above the present mesa surface, possibly an elevation of 800 feet or more above present sea level, or 300 or 400 feet above the present mesa level. Thus the San Diego formation of Pliocene age must have once extended far north of Mission Valley and possibly considerably east of its present limits. It is possible that a long still-stand of the sea during approximately middle Pliocene time represents the period when the Poway Terrace was developed by subaerial erosion; and possibly the old-land surfaces farther east can be correlated with it. If this explanation is correct, then the fine grain size of the silts and sands of the San Diego formation (containing relatively little gravel and cobbles) is explained by the subdued topography from which the somewhat sluggish Pliocene rivers derived their clastic loads. This mid-Pliocene time of low relief on the land (and high stand of the sea) appears to be represented in mountains east of the mesa lands by the subdued relief and old-land features described above.

Sometime after this approximately middle Pliocene period of submergence during which the San Diego formation was laid down, there began a slow uplift and tilting westward of the entire region

[106] Gale, H. R., in Grant, IV, U. S., and Gale, H. R., Mem. San Diego Soc. Nat. Hist., Vol. 1, pp. 45-49, diagram C (p. 47), 1931.

back as far as the escarpment on the east side of the present Peninsular Range in southern San Diego County. The early phases of the faulting which have left an impress on the present physiography of the mountainous region may have begun at this period. Possibly these newly inaugurated faults resulted in the formation of enclosed or partly enclosed basins within which some of the continental sediments were deposited by the revived streams.[107] The effect on the San Diego Mesa of this gradual uplift and tilt toward the west was to truncate and lower the surface of the recently deposited Pliocene sediments by wave scour at the profile of equilibrium. Also, the revived streams on the land to the east began bringing to the sea coarse material which was shifted alongshore and over the sea floor by the waves. The increased erosive power of the streams, alone, might account for the bringing to the sea of the gravel and cobbles which were later to be left on the truncated mesa as the Sweitzer formation, or faulting might have added heavy material to stream loads where fault scarps or shattered zones were athwart stream channels. The effect of this gradual uplift and westward tilt on the area east of the coast was to rejuvenate the region and inaugurate a new cycle of erosion. This new cycle was impressed upon the previous cycle which had not yet reached the peneplain stage but had probably attained early old age. During this period the Sweitzer formation, which lies nonconformably on the truncated mesa deposits, was formed as a stream supplied, but probably wave and current shifted, residual veneer on the shallowing sea floor.

This uplift and tilting continued, but probably at varying rates and with occasional periods of quiescence. During a time of rapid elevation the sea was unable to maintain its position over the submarine terrace of Pliocene sediments,[108] but was forced to retreat to the outer edge of the deposit where it began to cut a new terrace in them at a lower level. During the retreat of the sea off the mesa, it left behind beach ridges which still remain on the Linda Vista Mesa north of Mission Valley. At about this time or a little later it is probable that many of the prairie mounds were formed on the mesa by wind transportation of super-abundant loose clastic material not protected by an adequate cover of vegetation. Successive lower positions of the sea during the intermittent uplift resulted in the series of minor terraces which are still partly preserved on the outer marginal slope of the San Diego Mesa. The development of each lower terrace tended to areally reduce the next one above and it thus follows that the San Diego Mesa as a whole, and each lower terrace, may now be but a remnant of its former extent. Thus the continued but intermittent elevation of the land, possibly accompanied by a continuation of the westward tilt of the entire eastern orogenic block, resulted in the emergence of the San Diego Mesa and the cutting of a series of lower terraces on its seaward margin. The rivers on the land area to the east continued to be revived and were thus able to entrench themselves in steep-walled canyons below the general level of the old-land surface inherited from the previous (incomplete) erosion cycle. As soon as the San Diego Mesa emerged above the sea the larger streams, already well established in their valleys to the east, cut steep valleys through the relatively soft Tertiary sediments in their courses to the new more western shoreline of the sea.

The presence of what have been interpreted as submarine valleys off the coast of southern California, the great thickness of alluvium filling the bottoms of the major valleys in the San Diego Mesa, and the very incomplete known marine Pleistocene fossil record in San Diego County, all suggest an emergence of the coastal region to an elevation considerably above its present position during post-San Diego time. It was during this great emergence of the land that the larger rivers cut their beds so far below the present valley bottoms in the mesa region. Due to the much more resistant nature of the crystalline rocks east of the Tertiary sediments, none of the rivers were able to cut their channels below their present levels except in limited parts of their courses where local warping or the crushed nature of the rock near faults favored rapid erosion. Thus San Diego River and Sweetwater River at present flow over alluvial-filled valley floors in only limited parts of their courses in the foothills of crystalline rocks. It is possible that this great emergence occurred at the same time as the mid-Pleistocene

[107] Reed, R. D., "Geology of California," p. 22, footnote 2, 1933, Reed states: "Vertebrate fossils of probable upper Pliocene age have recently been found in extensive sedimentary deposits a few miles west of Warner's Hot Springs."

[108] The truncation of the mesa was sufficient to remove all of the Pliocene sediments north of the San Diego River, and also an unknown thickness of the Eocene below. Of course, it is possible that the mesa was truncated by wave erosion entirely on a landward retreating sea cliff which began as a notch on the outer edge of the emerged terrace.

orogenic disturbance (termed the Pasadenan Orogeny by Hans Stille) that folded and faulted so much of the Tertiary and lower Pleistocene strata in the Los Angeles-Ventura region, but there are no direct means of testing this possibility at the present time. The faults in the Peninsular Range of San Diego County may have been active at this time.

As stated by Stephens and others, the period of uplift appears to have been followed by a later submergence of the coastal region by the transgressing sea which reached a position approximately 100 feet above present sea level. It was probably during this late Pleistocene transgression that upper Pleistocene fossiliferous sands were deposited along parts of the shore of San Diego County. Too few facts have been obtained as yet to attempt a correlation of the steps in the Pleistocene history of this region with that of other regions, such as the Palos Verdes Hills near San Pedro or the terraces along the Malibu coast so interestingly discussed by Davis.

The latest physiographic events appear to be the slow reduction of sea cliffs and beach embankments, the construction of spits and bars and the growth of small deltas in bays and lagoons. As a whole, the coast now appears to be sinking slowly. This might be local or it might represent an eustatic rise of sea level.

This sequence of events in the post-Pliocene history of the San Diegan region must be considered largely hypothetical and unproved. Until much detailed field work can be accomplished little more can be said that is not largely speculative or at least based upon inadequate facts.

GENERAL RELATIONSHIPS TO OTHER REGIONS

The San Diegan region, whose physiography has just been briefly discussed, is a small part of what Fenneman[109] has referred to as the Lower California Province, and what Reed[110] has included in the Peninsular Ranges Province. The westward tilted and rejuvenated mountainous part of San Diego County has some similarity to the tilted fault block of the southern Sierra Nevada in east central California, but the eastern margin of the mountains in San Diego County is a more complex and irregular escarpment than that defining the eastern precipitous slopes of the southern Sierra Nevada and the rocks represented and their structures are only similar in part. However, in both regions old sedimentary rocks have been intruded by acidic plutonic rocks which may be of approximately the same age. The similarity of the Peninsular Range in San Diego County to the Santa Ana Mountains in Orange County is probably closer, although here again there are many important dissimilarities. Fairbanks, Hudson and others have mentioned the similarity and probable equivalence of some of the schists of the Cuyamaca Mountains of San Diego County with certain schists in the Santa Ana Mountains. The latter range is believed to be a fault block tilted westward by a fault zone along its eastern base. The San Pedro Martir Mountains, which form the mountainous backbone of the northern part of Lower California, Mexico, have been but little studied geologically but they appear to be an extension of the same general physiographic complex.[111]

The San Diego Mesa extends for some distance into Lower California, Mexico. Farther south extensive flows of vesicular lava have produced mesas which continue with interruptions as far as Ensenada, but only their general relationship to the San Diego Mesa was investigated by the authors. Other coastal terraces further south may be similar or actual physiographic equivalents.

The Tertiary strata of San Diego County are much thinner and less folded and faulted than those of the Los Angeles and Ventura Basins. The less disturbed structure of the Tertiary strata in the San Diego region may be due to their thinness and to the resistant nature of the crystalline rocks upon which they were deposited. The total absence of marine Oligocene and Miocene sediments is a striking feature. Correlations of the Pleistocene terraces of San Diego County with other California coastal regions may be possible in the future, but the basis of such correlations can only be obtained

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109 Fenneman, Nevin M., "Physiography of Western United States," (New York, 1931), pp. 508-510, and map of Physiographic Provinces.

110 Reed, Ralph D., "Geology of California," (Tulsa, Oklahoma, 1933), pp. 20-22, map fig. 1.

111 See Woodford, A. O., and Harris, T. F., "Geological Reconnaissance Across Sierra San Pedro Martir, Baja California," Bull. Geol. Soc. Amer., Vol. 49, no. 9, pp. 1297-1336, 5 figs., 7 pls., Sept. 1, 1938.

by much more field work than has been accomplished up to this time. Various fault blocks may have had a somewhat independent and individual history, so that long distance correlations may be, in most cases, very difficult if not entirely impossible.[112]

PRE-TERTIARY IGNEOUS AND METAMORPHIC ROCKS

The Tertiary sedimentary formations of the San Diego region are bordered on the east by a series of volcanic breccias and agglomerates which are believed to be of Triassic age. While there is no local paleontologic evidence upon which an age determination can be based, the northern extension of this foothill belt of ancient rocks was thought by M. A. Hanna[113] to be very similar in general characters to the dark gray or black slates and associated dikes and effusives which form the axis of the Santa Ana Mountains some miles to the north. These latter rocks were studied by Mendenhall[114] who collected from them specimens of *Rhynchonella, Spiriferina, Terebratula,* and fragments of crinoid stems determined by Stanton as of Triassic age.

The breccias and agglomerates of the San Diego region have not been observed in contact with the Cretaceous beds by the present authors, nor by Hanna in the area immediately adjacent to the north. As stated by Hanna, however, the Eocene can be observed to rest upon the eroded surface of the agglomerates, and because of this relation it is reasonable to assume that the Cretaceous likewise rests upon an erosion surface of these pyroclastics. Further evidence of the considerable age of these agglomerates is their relationship to a quartz diorite batholith which has been intruded into them. In the Grossmont-Mount Helix region just east of La Mesa the diorite mass contains numerous xenoliths of the dark, dense agglomerate or pyroclastic rocks which determine their age as pre-batholithic. A few miles north of La Mesa, Hanna (1926, p. 200) has observed roof pendents of these older rocks surrounded by the quartz diorite.

In the region covered by the present report the agglomerates appear to occur in a band of varying width along the western margin of the quartz diorite batholith. This band extends from the northeastern portion of the area mapped, in a south-southeasterly direction to and probably beyond the Mexican Boundary.

East of this band of old agglomerates and volcanics a quartz diorite batholith is the most important country rock. This plutonic rock has intruded a considerable number of other rocks, some of which are schists which may have been ancient Paleozoic sediments. Fairbanks[115] gave an interesting account of the geology of the mountains of San Diego County in a report published by the California State Mineralogist in 1893. In his report, which includes a large number of field observations and determinations of igneous and crystalline metamorphic rocks, it appears that the region is a complex one petrographically. Fairbanks (1893, p. 116) mentioned the discovery in the Santa Ana Mountains of a gray limestone containing "fine specimens of a bivalve shell, and faint traces of corals and univalve shells" which were determined at the U. S. National Museum as of Carboniferous age. As pointed out by Hudson,[116] these fossils probably came from Ladd Canyon and were the ones which J. P. Smith[117] once considered probably lower Triassic in age. Later Smith[118] named the bivalve *Daonella*

112 In a recent paper, W. M. Davis (Proc. Nat. Acad. Sci., Vol. 18, no. 11, pp. 659-665, 8 text figs., Nov., 1932; Bull. Geol. Soc. Amer., Vol. 44, no. 5, pp. 1041-1133, 26 text figs., 16 pls., Oct., 1933) has given an interesting description of the marine terraces along the Malibu coast of Los Angeles and Ventura Counties, with a suggestion of a correspondence with the glacial chronology of the Sierra Nevada. Even if these terraces were due entirely to periodic eustatic changes in the level of the sea, which is not proved, their correspondence to terraces on other land blocks some distance away may be confused or entirely obscured by diastrophism in the second region. Lack of abundant fossils on these Quaternary terraces generally makes paleontologic correlations impossible. All the terraces in the Malibu region discussed by Davis are, in all probability, late Pleistocene and therefore they do not represent the major glacial sub-epochs of Pleistocene times.

113 Hanna, Marcus A., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, no. 7, p. 203, 1926.

114 Mendenhall, W. C., U. S. Geol. Surv., Prof. Paper 71, p. 505, 1912.

115 Fairbanks, H. W., Calif. State Mining Bureau, 11th Ann. Rept. State Mineralogist, pp. 76-119, 1 map, 1893.

116 Hudson, F. S., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 13, no 6, pp. 188-189, 1922.

117 Smith, J. P., Proc. Calif. Acad. Sci., Ser. 3, Vol. 1, p. 352, 1904.

118 Smith, J. P., U. S. Geol. Surv., Prof. Paper 83, p. 145, 1914. *Daonella sanctae-anae* Smith is figured on pl. 1, figs. 12-14. In regard to horizon and locality of this species, Smith stated (p. 145): "Rare in the Middle Triassic, near the head of Silverado Canyon (probably Bedford Canyon), Santa Ana Mountains, Orange County, Cal., associated with *Rhynchonella* sp. undt., and a rough-shelled ammonite not definitely determinable. Collected by H. W. Fairbanks."

sanctae-anae and, presumably due to the apparent close relationship of this new species to *Daonella böckhi* Mojsisovics of the middle Trias of the Alpine Province, he referred the beds from which this species was collected to the middle Triassic. In the meantime Stanton had concluded that the Ladd Canyon fossils could be taken to "clearly indicate the Triassic age of the fauna," which he believed was "probably upper Triassic rather than older." The importance of the age determination of these Santa Ana Mountains schists and associated limestone[119] is that they appear to be equivalent to some of the metasedimentary rocks of the mountains further south in San Diego County, as early suspected by Fairbanks.

Hudson[120] has contributed an important paper on the crystalline rocks of the Cuyamaca region in San Diego County. This paper was a result of his study of the gold deposits which had been mined there. He states (p. 181): "The rocks exposed at the surface over a large part of the mountainous region of San Diego County are quartz-bearing plutonic rocks, varying from quartz diorite to true granite in composition. The relation of these rocks to the older rocks which they have intruded shows that the intrusion was of batholithic nature. Most of the cover has been stripped from this batholith, the older rocks being found as remnants, surrounded by granite. These older rocks are schists, the result of metamorphism of shales and sandstones, with subordinate layers of lava." In the Cuyamaca region Hudson reports the occurrence of basic plutonic rocks, such as basic diorite, gabbro and norite, as well as pegmatites which, in parts of San Diego County, are important sources of gem minerals such as Tourmaline, Kunzite, Beryl, etc. In regard to the date of intrusion of the quartz diorite Hudson states: "The quartz-diorite batholith was developed in post-Triassic time and is probably equivalent to the post-Mariposa intrusions of the Sierra Nevada."

A number of short papers have appeared from time to time bearing on minerals or special rock types occurring in San Diego County. Among them may be mentioned papers by Lawson, Schaller and others. References to these papers may be readily found in the various bibliographies by Nickles[121] and Shedd.[122] An excellent brief summary of the crystalline rocks of San Diego County appears in an important work by Reed[123] on the geology of California. More recently Miller[124] briefly described the geology of a section across a portion of San Diego County. In this paper he described principally the igneous and metamorphic rocks observed in an area contiguous to the highway through La Mesa, Descanso, Jacumba to just beyond Mountain Springs in Imperial County.

Igneous rocks are rare in the coastal region of San Diego County. However, it is of interest to note that Blake[125] reported the presence of a dike of greenstone along the southeast side near the southern end of Point Loma. Although we have not seen this dike we believe the sedimentary beds cut by the intrusion are of Cretaceous age. A basaltic dike said to be from two to thirty feet thick occurs about a quarter of a mile north of the pier of the Scripps Institution of Oceanography and about 2¼ miles north of La Jolla. It cuts the Rose Canyon shale and is exposed along the beach but does not extend to the top of the high bluff. It is the only igneous intrusion in the Eocene of which we are aware in this region. It has been described by Fairbanks[126] and by M. A. Hanna.[127] The only

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119 H. W. Hoots (U. S. Geol. Surv., Prof. Paper 165-c, pp. 88-89, 1931) referred the Santa Monica slate of the eastern part of the Santa Monica Mountains (Los Angeles County) questionably to the Triassic, "in view of its similarity to the fossiliferous Triassic slate of the Santa Ana Mountains, both in lithologic character and in its relations to fossiliferous Cretaceous rocks and an earlier granitic intrusion." It might be mentioned that the Santa Monica slate, which is a formation characterized chiefly by its total lack of recognizable fossils and its rock cleavage parallel to the original bedding planes, bears considerable resemblance to some phases of the Franciscan formation of the coast ranges of middle and northern California (probably of Jurassic age in part) and likewise to some statically metamorphosed argillites and phyllites, with cleavage parallel to the bedding planes, occurring in parts of the Mojave Desert and, by their geologic relations, believed to be of pre-Cambrian age. The similarity of these latter mentioned rocks was called to our attention by Professor A. R. Whitman.

120 Hudson, F. S., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 13, no. 6, pp. 175-252, 7 text figs., 1 map, pls. 9-14, June 29, 1922.

121 Nickles, J. M., U. S. Geol. Surv., Bull. 746, 1923; Bull. 747, 1924; Bull. 823, 1931.

122 Shedd, S., State of California, Dept. Nat. Resources, Division of Mines, Geologic Branch, Bull. 104, 1933; Bull. 115, 1937.

123 Reed, R. D., "Geology of California," published by the Amer. Assoc. Petrol. Geol., Tulsa, Oklahoma, May, 1933.

124 Miller, W. J., "A Geologic Section Across the Southern Peninsular Range of California," Calif. Journ. Mines and Geology, Vol. 31, no. 2, (31st Rept. State Mineralogist), pp. 115-142, 8 text figs., 1 plate (geologic map and sections), 1935.

125 Blake, W. P., U. S. Pacific R. R. Repts., Vol. 5, p. 176, 1856.

126 Fairbanks, H. W., 11th Ann. Rept. Calif. State Mineralogist, pp. 96-97, 1893.

127 Hanna, M. A., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, no. 7, p. 224, 1926.

indication in this region of igneous activity during Eocene time is the rare occurrence of ash beds in the Poway conglomerate. The occurrence of bentonite in this region is mentioned in the discussion of the Pliocene sediments in the present paper.

During the course of the field work in this area, the authors collected a number of hand specimens of rock from the granitic batholith and from the volcanics and agglomerates to the east of the Pliocene beds. Thin sections of twelve of these specimens were made by Hochgesang and Vogel in Goettingen, Germany. The hand specimens were studied by the late Dr. John E. Wolff of Pasadena, California, and the thin sections were studied by Dr. Wolff and by Dr. Gordon A. Macdonald whose reports are included here. Their names accompany the descriptions which each has furnished.

No. 1. From south side of Sweetwater Dam, close to the upper part of the dam:

HAND SPECIMEN. Dark gray, dense, breccia, the rock fragments even smaller than in No. 2.

SECTION. The rock fragments are the same as those of Nos. 2 and 3, i.e., fine-grained feldspar or quartz feldspar lavas, often graphic, but one is a fine-grained granite porphyry, with phenocrysts of quartz and feldspar in a microgranitic groundmass, and another is perhaps a silicified tuff from the same rocks. The cement has broken fragments of the same rocks, quartz feldspar, occasional fragments of ferromagnesian minerals now replaced by epidote, calcite and iron ore; large areas of calcite and epidote, the base of the cement, as before, fine silica grains and sericite. (J. E.Wolff).

No. 2. From foundation rock of Sweetwater Dam, taken from north side, 6 to 9 feet from the top of the concrete work. This rock weathers light buff gray or becomes stained brownish red from iron oxide.

HAND SPECIMEN. A dense dark gray breccia, with small fragments of rock, biotite or chlorite, and frequent small masses of pyrite.

SECTION. Finer-grained than No. 3. The rock fragments are smaller, but essentially the same, of fine-grained quartz feldspar graphic inter-growths, with occasional phenocrysts of orthoclase and plagioclase. The cement again essentially a fine-grained quartz aggregate and plates of sericite, with broken feldspar (orthoclase and acid plagioclase fragments), pyrite and magnetite areas, much epidote, sericite, etc., in the altered feldspars; chlorite, clastic augite, sometimes replaced by uralite, calcite, quartz fragments. (J. E. Wolff).

No. 3. Breccia from south side of upper Las Choyas Valley, just south of the V in valley:

HAND SPECIMEN. Small fragments of feldspar, etc., in a dark gray, quartzitic groundmass.

SECTION. A number of large and small rock fragments in a cement. The rock fragments are largely of fine-grained igneous rocks, having fine feldspar laths in flow structure, with or without quartz between. Some seem identical with the alaskite-porphyry, below, others are pure feldspar, a plagioclase too fine to determine, one of fine-grained biotite granite, and others composed of fine interlocking quartz grains, a quartzite or chert, others contain larger angular grains of quartz and feldspar in the same fine quartz aggregate—a silicified arkose or tuff. Also a limonitized limestone. The cement of the tuff has small similar rock fragments, fragments of quartz and feldspar, much epidote, chlorite, limonite and so forth, the ultimate cementing material minute grains of quartz and sericite. (J. E. Wolff).

No. 4. Rock samples from west side of Lower Otay Dam:

HAND SPECIMEN. A dense dark gray flinty rock, through which ill-defined and evidently altered feldspar phenocrysts are scattered.

SECTION. The feldspar phenocrysts are orthoclase and a plagioclase probably albite, much decomposed, with epidote, quartz, calcite as products. One or two bunches of secondary green hornblende may represent original augite. The groundmass has small slender feldspars, largely albite-oligoclase, probably orthoclase, with quartz filling, and decomposition products. The rock is probably identical with No. 8, but much changed, i.e., an alaskite-porphyry. (J. E. Wolff).

No. 5. Sample from hillside about 1 mile west of Sweetwater Dam:

HAND SPECIMEN. Dense dark gray with little pyrite areas common and small phenocrysts of feldspar.

SECTION. Large phenocrysts of colorless augite, largely replaced by epidote aggregates, and of basic oligoclase, also epidotized. The groundmass is composed of small laths of oligoclase, scattered in what was once a glass, now a mass of granular decomposition products. The rock is probably an augite-andesite? (J. E. Wolff).

No. 6. One-half mile southwest of Grossmont High School, on north slope of Grossmont, just above foot of the mountain:

HAND SPECIMEN. A coarse-grained, feldspar-rich and hornblende-poor rock, containing patches of a finer-grained more basic feldspar-hornblende rock, in which a rough ratio is two hornblende to three feldspar. (J. E. Wolff).

SECTION. *Coarse-grained facies*: Hypidiomorphic texture. Plagioclase is the most abundant constituent, and shows well-developed zoning, from acid labradorite in the center to oligoclase on the outside. Interstitial quartz is abundant. The ferromagnesian minerals are green hornblende and less abundant brown biotite. Minor accessory minerals include abundant magnetite, less abundant apatite and titanite, and a few crystals of zircon.

Fine-grained facies: A basic inclusion, composed of the same minerals as the coarse-grained rock, but with a greater percentage of dark minerals, and a smaller amount of biotite in relation to hornblende. A little orthoclase is also present, as large crystals carrying poikilitic inclusions of andesine and hornblende.

The rock is a hornblende-biotite quartz diorite, containing basic inclusions of schlieren. In the San Luis Rey quadrangle just to the north, Hurlbut (Amer. Mineralogist, Vol 20, pp. 609-630, 1935) considers the dark schlieren to have been derived by reaction of the quartz diorite with xenoliths of the older San Marcos gabbro. (G. A. Macdonald).

No. 7. West slope of Grossmont, about one-half way up, just east of La Mesa:

HAND SPECIMEN. Fine-grained pinkish biotite-granite. Scattered feldspars are decomposed to limonite. (J. E. Wolff).

SECTION. The texture is hypidiomorphic. Essential minerals are orthoclase and quartz, with a little microcline, and a subordinate amount of oligoclase. The ferromagnesian mineral is brown biotite. Accessory minerals include magnetite, apatite, titanite, and zircon, the latter enclosed in the biotite and surrounded by pleochroic halos. The biotite is in subhedral plates, and the oligoclase varies from subhedral to nearly euhedral in outline. Orthoclase varies from subhedral to anhedral. The quartz was clearly the last mineral to crystallize, occurring as anhedral grains intersticial to the other components. The rock is slightly altered; the orthoclase shows traces of kaolinization, and a few of the biotite flakes are partly changed to chlorite.

The rock is a biotite granite. (G. A. Macdonald).

No. 8. First hard rock outcrop on hillside, east margin of Otay Mesa, at east end of main east-west road:

HAND SPECIMEN. A lighter gray and coarser rock than No. 9; numerous small phenocrysts of feldspar. Limonitized pyrite grains. (J. E. Wolff).

SECTION. Porphyritic, with phenocrysts of albite in a groundmass composed of small laths of albite and intersticial quartz. Small, irregular areas of epidote, chlorite, and calcite are scattered through the slide. A little magnetite is present.

The larger phenocrysts, which Wolff identified as orthoclase, show a positive sign, with 2V about 75° and an index lower than balsam, and are certainly albite.

The rock is an albitite. (G. A. Macdonald).

No. 9. From north slope of 667 foot hill, north side of Otay Valley about 3¼ miles west from lower Otay Dam:

HAND SPECIMEN. A dark gray, fine-grained rock, showing small crystals of feldspar, small specks of pyrite common, and large vein-like or concretionary masses of pyrite, quartz and a white granular mineral. (J. E. Wolff).

SECTION. The rock is very much altered, but I believe it represents a propylitized andesite. Phenocrysts of some femic mineral, probably augite, have been changed to epidote and chlorite. The feldspars have been saussuritized, and are now represented by mixtures of albite, epidote, chlorite and calcite. There are also present abundant fine, irregular grains of iron ore, some of them no doubt original, but many being separated out during the change of the femic minerals to chlorite, with which they are closely associated. (G. A. Macdonald).

No. 10. About 300 yards east of Isham Springs, Sweetwater Reservoir:

HAND SPECIMEN. A dark flinty rock with irregular pinkish-white areas evenly distributed in a dark gray groundmass.

SECTION. The rock is mainly composed of a fine, interlocking aggregate of quartz grains, in which are scattered fragmentary crystals of larger size feldspars, mostly andesine, also patches of muscovite or chlorite plates, little grains of ore, often with associated rutile crystals, much epidote. The feldspars are clastic, the rest metamorphic, an altered sediment, perhaps a tuff. (J. E. Wolff).

No. 11. About ¾ mile north of Aloha, edge of mesa, north of Sweetwater Valley:

HAND SPECIMEN. Dark gray, fine-grained basaltic rock, small phenocrysts of feldspar.

SECTION. Small phenocrysts of a very basic labradorite (bytownite) are common, and a few of augite. The groundmass is composed of similar feldspars in flow structure, and small grains of augite and magnetite, with perhaps a very little interstitial glass here and there. Epidote, chlorite and other alteration products. The rock is a feldspar basalt. (J. E. Wolff).

No. 12. In road pass about 1½ miles east of summit of Mount Helix:

HAND SPECIMEN. A fine-grained, biotite-rich, granitic rock; the feldspars have a slight lilac color. (J. E. Wolff).

SECTION. Hypidiomorphic texture. Essential minerals are andesine, orthoclase, and quartz. The andesine shows distinct zoning, varying from intermediate andesine (An_{40}) in the center to acid andesine (An_{33}) on the outside. The andesine is much more abundant than the orthoclase. Ferromagnesian minerals include green hornblende and brown biotite, in part intergrown. Many of the hornblendes contain a central core of diopsidic augite, the c crystallographic axis in the augite being parallel to that in the enclosing hornblende. The properties of the augite are: $(+)2V = 60°$, very weak, $Z\ c = 40°$. Minor accessories are magnetite, apatite, zircon, and titanite. Some of the biotite is slightly chloritized.

The rock is a hornblende-biotite quartz diorite. Wolff's designation of the rock as a granodiorite seems to me undesirable, since a granodiorite should contain about half as much orthoclase as it does plagioclase, while this rock carries very much more abundant plagioclase than it does orthoclase. (G. A. Macdonald).

No. 13. Igneous rock outcropping ½ mile north of Aloha and ⅝ mile W-NW of Sweetwater Dam:

HAND SPECIMEN. The rock is a fine-grained, dense, greenish-gray basalt.

SECTION. Microscopically, it consists of phenocrysts of labradorite and diopside in a pilotaxitic groundmass of labradorite laths and grains of serpentinized diopside, with abundant small grains of magnetite. The feldspar phenocrysts are slightly zoned, varying from medium labradorite in the center to acid labradorite on the edges. Some oscillatory zoning is present. The feldspar microlites in the groundmass are acid labradorite. Diopside is very largely altered to serpentine, usually showing a net structure; but a few grains of diopside remain unaltered. (G. A. Macdonald).

Of these rock specimens Nos. 6, 7 and 12 are from the granitic batholith, while the others are from the volcanics and agglomerates. Nos. 1, 2 and 3 appear to be much altered tuffs, probably originally of andesitic nature. Nos. 4 and 8 are albitite, Nos. 5 and 9 altered augite andesites, No. 6 a quartz diorite, No. 7 a biotite granite, No. 10 probably a tuff, Nos. 11 and 13 are basalts, and No. 12 a diorite.

CRETACEOUS

Marine beds of Cretaceous age which underlie the Eocene in the area under discussion are exposed at only a few places. They are found principally near the coast, due to the fact that the Eocene strata over most of the area have not been elevated sufficiently to permit recent erosion to cut through to the lower beds. In the La Jolla Quadrangle, M. A. Hanna[128] discussed the Cretaceous deposits which are exposed along the coast from about one-half mile north of False Point to north of the City of La Jolla, and also on the north slope of Mount Soledad. These beds, which were referred to the Chico, upper Cretaceous age, are about 500 feet thick and consist of shales and sandstones of varying hardness. The Cretaceous sandstones forming the terrace upon which La Jolla has been built are resistant to erosion, but joints, faults and irregular induration have permitted wave action to produce numerous caves and small coves due to the more rapid removal of the softer material. Eocene rocks unconformably overlie the Cretaceous beds in that area.

Farther south, on the west side of Point Loma from west of the Theosophical Institute up to and including the southern point of the peninsula, Cretaceous shales and sandstones are well exposed close to the water's edge. Fairbanks[129] briefly discussed the geology of Point Loma and referred briefly to these Cretaceous beds. He assigned the beds at the southern end of Point Loma to the Chico, upper Cretaceous, but supposed the heavy overlying conglomerates to be of late Tertiary age,[130] whereas it seems more probable that they belong to the upper Eocene. They apparently unconformably overlie the Cretaceous strata.

At the extreme south end of Point Loma, a thin-bedded bluish gray shale occurs at the base of the cliff. These strata are well exposed for over a hundred yards east of the small cave near the lighthouse. The dip of these beds is about 11° toward the east, and they soon disappear beneath the rocky beach. In these shales the authors collected a few specimens of *Baculites* and fossils of a plant identified by Dr. L. M. Waitzinger as a conifer of ancient type. From this locality (Loc. 1173 C.A.S.)

[128] Hanna, M. A., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, no. 7, pp. 205-207, 1926. — See also, Hertlein, L. G., and Grant, IV, U. S., Calif. Journ. Mines and Geol., Vol. 35, no. 1. 35th Rept. Calif. State Mineralogist, pp. 62-65, Jan., 1939 [received at library of the California Academy of Sciences, Aug. 23, 1939].

[129] Fairbanks, H. W., Calif. State Mining Bureau, 11th Ann. Rept. Calif. State Mineralogist, pp. 94-96, 1893.

[130] Fairbanks (1893, p. 96), however, did report the occurrence of Eocene fossils in the low bluffs at the northeast end of Point Loma.

Mr. C. C. Church, paleontologist with the Tidewater Associated Oil Company, has identified foraminifera in a sample of dark gray shale. He has submitted to us the following report on these foraminifera:

The foraminifera listed here were concentrated from gray shale collected by Dr. L. G. Hertlein in September, 1928. The preservation is good but the total number of specimens recovered is small. For the number of specimens the list of genera is relatively short. The species are as follows:

Anomalina sp.
Allomorphina cf. *minuta* Cushman
Bulimina obtusa d'Orbigny
Globotruncana arca Cushman
Gyroidina sp.
Gaudryina (*Pseudogaudryina*) *pyramidata* Cushman
Gaudryina oxycona Reuss
Marginulina humilis Reuss
Robulus sp.
Spiroplectammina anceps Reuss

These foraminifera are commonly found near the middle of the upper Cretaceous, that is, below the Moreno and probably in the upper half of the Panoche group of F. M. Anderson.

The Eocene beds overlying the Cretaceous at Point Loma are composed of sandstones and conglomerate. These Eocene beds at one place near the point dip about 30° to the east-southeast. Boulders made up of sandstone are present, and near the top huge boulders occur which apparently came from the crystalline rocks many miles to the east. Both the Cretaceous and Eocene are cut by faults.

A number of species have been listed from the Cretaceous of Point Loma by Cooper[131] and Anderson.[132] The published lists of the species from that locality are in need of revision, as some of the species cited are now known to occur in the Eocene or at other localities in the Cretaceous and not at Point Loma.

The list here given has been compiled from published lists and from collections in the California Academy of Sciences.

BRACHIOPODA

"Waldheimia" imbricata Cooper

PELECYPODA

Acila demessa Finlay
Coralliochama orcutti White
Crassatellites lomana Cooper (type locality)
Cymbophora ashburnerii Gabb
Glycymeris veatchii Gabb
Inoceramus sp.
Lima appressa Gabb
Nemodon vancouverensis Meek
Opis triangulata Cooper (type locality)
Pholadomya brewerii Gabb
Protocardium placerensis Gabb
Tellina decurtata Gabb
Tellina whitneyi Gabb
Trapezium carinatum Gabb
Trigonocallista varians Gabb

GASTROPODA

Acteonina pupoides Gabb
Cerithium pillingi White
Gyrodes conradiana Gabb
Haliotis lomaënsis Anderson (type locality)
Oligoptycha obliqua Gabb
Patella cf. *traskii* Gabb

[131] Cooper, J. G., Calif. State Mining Bureau, Bull. 4, pt. 5, pp. 60-63, 1894. See also, Cooper, A. S., Calif. State Min. Bur., Cat. State Mus. Calif., (Sacramento), Vol. 5, pp. 118-122, 1899.

[132] Anderson, F. M., Proc. Calif. Acad. Sci., Ser. 3, Geology, Vol. 2, no. 1, pp. 27-32, 1902.

CEPHALOPODA

Baculites fairbanksi Anderson
Hamites vancouverensis Meek
Heteroceras cooperii Gabb (type locality)
Parapachydiscus catarinae Hanna and Anderson

This assemblage indicates an upper Cretaceous age, probably Campanian, upper Senonian.

Mr. Frank Stephens and Mr. Cecil V. Robinson discovered a new Cretaceous fossil locality near the southern end of Point Loma which has yielded specimens of *Parapachydiscus catarinae* Hanna and Anderson,[133] *Coralliochama orcutti* White,[134] *Volutoderma gabbi* White, *Inoceramus* sp. and other mollusks. The *Parapachydiscus* and the *Coralliochama* also occur in the northern district of Lower California, the *Parapachydiscus* in the Santa Catarina region and the *Coralliochama* at Punta Banda, Lower California, Mexico. The *Parapachydiscus* also occurs in the upper Cretaceous north of Coalinga, Fresno County, California. These occurrences indicate that this *Parapachydiscus* zone is of considerable importance for purposes of correlation.

A well drilled by the Borderland Exploration Company on Point Loma gives some definite data on the thickness of the Cretaceous beds at that locality. This well, which was known as Point Loma No. 1, was located on Pueblo Lot No. 211, section 30, Township 16 South, Range 3 West, San Bernardino Base and Meridian, and was drilled to a depth of 5,101 feet. The log furnished through the courtesy of G. D. Hanna and C. C. Church is as follows:

1,560 feet. Core. Hard gray sandy shale; plant fragments.
1,580 feet. Core. Hard gray sandy shale; plant fragments, foraminifera, fragments of *Inoceramus* and ammonites.
1,680 feet. Core. Hard gray sandy shale; plant fragments and ammonite fragments.
1,787 feet. Core. Hard gray sandy shale; plant fragments.
1,885 feet. Core. Hard gray sandy shale; plant fragments.
1,945 feet. Core. Hard gray sandy shale; fragments of *Baculites chicoensis* Trask.
2,000 feet. Core. Hard gray silty clay shale; foraminifera rare and small, *Textularia, Silicosigmolina, Marginulina.* Foraminifera in core appear to be Cretaceous, but determination not certain.
2,010 feet. Core. Hard gray sandy shale; plant fragments.
2,100 feet. Core. Coarse greenish pebbly sandstone.
2,250 feet. Bit. Gray fine to coarse sand and shale; no fossils.
2,500 feet. Core. Hard gray sandy shale; plant fragments, foraminifera and a large piece of an ammonite.
2,771 feet. Core. Hard reddish brown sandstone with pebbles; marked "top of red beds."
3,110 feet. Core. Hard red sandstone.
3,670 feet. Core. Hard red conglomerate; pebbles up to 3 inches. All samples with fossils are Cretaceous. The red beds are of uncertain age; nothing similar to this in West Coast Cretaceous, so may be older.
3,735 feet. Core. Hard greenish-gray altered rock, probably metamorphosed rhyolite or similar form. In thin flakes under the microscope the substance is seen to be translucent. It contains no sand or quartz and does not belong to the granite series. Pyrite and calcite are found in seams and the rock itself contains some mineral which reacts like dolomite in hot acid, although the proportion is small.
3,828 feet. Core. Greenish-gray, partially crystalline, limy, altered rock with veinlets.
3,857-58 feet. Core. Brown loose fine sand; no fossils. The brown sand of the last sample is so loose as to seem out of place with the dense limy rock a few feet above it. No fossils were noted to indicate the possible age of the material.

[133] Hanna, G. D., and Anderson, F. M., Pan-American Geologist, Vol. 50, no. 4, p. 283, pl. 9 (larger shells in the illustration), Nov., 1928. Name and figure only. ". . . from a few miles southwest of Santa Catarina, and from the uppermost beds of the Cretacic section exposed there." Lower California. — Anderson and Hanna, Proc. Calif. Acad. Sci., Ser. 4, Vol. 23, no. 1, p. 19, pl. 1, fig. 1, pl. 2, fig. 1, pl. 3, figs. 1-3, Dec. 23, 1935. "Near Santa Catarina Landing, Lower California." Upper Senonian, upper Cretaceous. — Johnson, M. E., "West Coast Shells," (Edwards Brothers, Inc., Ann Arbor, Michigan), 1937, p. 38, fig. 114 (figure at right). Near Catarina, Lower California.

[134] For references to *Coralliochama orcutti* White see Anderson, F. M., and Hanna, G. D., Proc. Calif. Acad. Sci., Ser. 4, Vol. 23, no. 1, p. 31, 1935. Definitely recorded from Point Loma and La Jolla, Calif. H. W. Fairbanks (1893, pp. 95, 96) recorded the species from the same localities, and Stearns (Science, New Ser., Vol. 12, no. 294, p. 248, Aug. 17, 1900), also recorded the species from La Jolla.

Rudistids are comparatively rare in the Cretaceous of western North America. Packard and Lupher have described two rudistids, one from the Jurassic, and one from the Cretaceous of Oregon (Univ. Oregon Publ. Geol. Ser., Vol. 1, no. 3, pp. 203-212, 6 pls., issued Dec. 30, 1929). Orcutt stated (Jamaica Nat., Vol. 1, no. 1, 1927, p. 3), that the genus *Coralliochama* had been reported from Washington.

4,290 feet. Core. Light gray, hard, fine-grained crystalline rock with seams of calcite. This confirms the determination made higher in the well that the formation is non-sedimentary.

This well was drilled to 5,101 feet, where brownish gray shale and sandstone were logged.

From this log it appears that the marine Cretaceous beds ("Chico") at this locality are not more than 1,211 feet thick. If the red beds (964 feet) are non-marine Cretaceous, as seems likely, then the total thickness of the Cretaceous here is not more than 2,175 feet.

The log of the Holderness well, near the mouth of the Tia Juana River, given in a later part of the present paper (page 59) shows that the marine Cretaceous is not more than 1,360 feet thick in that area. The underlying red beds,[135] 269 feet thick, may be non-marine Cretaceous, in which case the total thickness of Cretaceous beds in that area would be 1,629 feet. The dip of the beds penetrated by the wells is unknown to us and therefore their exact maximum stratigraphic thickness is unknown.

Information from Mr. Donuil Hillis, geologist with the Capital Company, San Francisco, and Dr. A. L. Tull, San Diego, on Capital No. 1 Well was recently made available to us. This well is stated to be "150 feet east and 547 feet north of the southwest corner of Pueblo Lot 1237, which would be in the Projected Section 32, of Township 15 South, Range 3 West" (Hillis). According to Mr. Hillis (letter to U. S. Grant, IV, dated at San Francisco, September 11, 1942), Dr. Tull believed the Cretaceous was encountered at a depth of 4,400 feet and the well was still in rocks of that age at 6,130 feet. The data supplied by Mr. Hillis and Dr. Tull indicate a considerably greater thickness of both Eocene and Cretaceous than that known from the outcrop sections. Due to the fact that the Cretaceous lies upon an uneven erosion surface it is likely that thicknesses will vary considerably. This well is near Rose Canyon, where folding along the Soledad anticline might give a somewhat exaggerated stratigraphic section in a well.

The following additional information on Capital No. 1 Well was provided by Mr. Charles H. Reed, Secretary-Engineer, Bureau of Mines of San Diego County, in oral statements to Mr. Clinton G. Abbott on March 3, 1943, and a letter to him on April 30, 1943. The formations encountered in drilling were entirely sedimentary. The ultimate depth of 6,130 feet is deeper than any other well ever drilled in San Diego County except one at Imperial Beach, which struck salt water at 6,400 feet. On March 3, 1943, there were 850 feet of fluid in the bottom of Capital No. 1 Well, of which 30% was water and 70% was oil of 24.8 gravity. The temperature of the water was 168° F. Mr. Reed believed that strata producing oil and gas were penetrated by the well between the depths of 5,904 and 6,130 feet. He further stated that drilling was suspended about the latter part of August, 1942, and that, due to mechanical difficulties, it was impossible to drill the well deeper.

Many years ago a vertical shaft was sunk to a depth of about 125 feet on the terrace on the west side of Point Loma, approximately one and three-fourths miles north of the present lighthouse, in search of coal.[136] It is said that several strata of coal were penetrated, one of them being five feet thick and having a dip toward the east.[137] Although we visited the entrance to this shaft we were

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135 These red beds may be a southern extension of the Trabuco formation in the Santa Ana Mountains, Orange County, Calif. This formation was named by E. L. Packard, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 9, no. 12, p. 140, Feb. 8, 1916. See also, Popenoe, W. P., Journ. Geol., Vol. 49, no. 7, pp. 738-752, 1941.

The red conglomerate resting on the diorite at Punta Banda, on the south shore of Todos Santos Bay, about seventy-five miles south of the United States-Mexico Boundary, may likewise represent the Trabuco formation. At that locality the fossiliferous Cretaceous is in fault contact with the red beds.

136 The San Diego Herald (Vol. 5, Nov. 24, 1855, p. 2, col. 1), stated that coal was discovered by Ladd, Green, Tanner and Serrine on the shore of the Pacific about two miles north of Point Loma. It was tested and found to burn with a clear flame, and gave off intense heat. The following year the same paper (Vol. 5, Feb. 2, 1856, p. 2, col. 2), stated that the company had bored 45 feet and passed through 10 or 12 different strata of coal, which varied from three inches to one foot in thickness.

Smythe wrote regarding this mine as follows:

"One of the most interesting episodes of the early days was the work of some Mormons, bent upon the enterprise of mining coal on the north [west] shore of Point Loma, late in 1855, in response to a 'revelation.' Obtaining a lease of land from the city trustees they proceeded to make borings which penetrated several strata of coal, ranging from three inches to a foot in thickness. In April, 1856, they announced that they had discovered a vein of good coal four and a half feet thick near the old lighthouse on Point Loma, and began to sink a shaft. Considerable machinery was installed and a few experienced miners, as well as engineers, employed, but nothing came of the enterprise." See Smythe, William E., "History of San Diego," (The History Co., San Diego, Calif., 1907), pp. 259-260.

A modern account of the history of this mine by Winifred Davidson (Mrs. John Davidson), occurs in the San Diego Union, second section, Sunday Morning, Jan. 31, 1932, p. 2, col. 4, 1 illustration.

137 San Diego Herald, June 28, 1856, p. 2, col. 1.

unable to determine whether the coal was of Eocene or Cretaceous age. That this shaft penetrated beds of Cretaceous age, however, is certain since Gabb described *"Ammonites" cooperii,* an upper Cretaceous form, "from a shaft sunk in search of coal on the west side of Point Loma, opposite La Playa, San Diego."[138] A map[139] by C. B. Wadleigh published in 1888 bears the words "Coal measures" in the ocean off this part of Point Loma.

A few miles farther north, coal was encountered in a boring at La Jolla which Fairbanks (1893, p. 96) said must be Cretaceous in age. Cretaceous rocks are exposed there, but we have no later information on the occurrence of this coal.

Blake reported the presence of a dike of greenstone along the southeast side of Point Loma. We did not investigate this dike, but we believe that it cuts Cretaceous sediments. Another dike occurs near the Scripps Institution of Oceanography north of La Jolla and cuts the Eocene rocks there.

EOCENE

In his report on the geology of the La Jolla Quadrangle Marcus Hanna[140] briefly reviewed the literature on that area and gave a complete list of references. Hanna's paper is the most complete report yet published on the Eocene in the area immediately north of the San Diego Pliocene basin and the reader is referred to it for details which need not be repeated here. The following table, taken without change from Hanna's report on the paleontology of the La Jolla Quadrangle, is an excellent summary of his treatment of the stratigraphy:

				Thickness in feet
Pliocene, San Diego formation				
	Unconformity			
Eocene	Tejon Formation	Poway conglomerate	Massive conglomerate, boulders well rounded, largely porphyritic volcanics; coarse; cross-bedded yellow and brown sands; some fine shaly sands with partings well developed due to mica; upper part contains considerable soft white caliche	1000
	Unconformity, at least in part.			
	La Jolla Formation	Rose Cañon shale	Light gray mudstone, slightly laminated in places; gray and yellow sandy shale; yellow and brown sands; in upper part lenses of conglomerate, boulders well rounded, largely porphyritic volcanics, but some of the underlying mudstones and sands	300
		Torrey sand	Massive, white, coarse-grained, cross-bedded sand, arkosic and sometimes carrying much muscovite and biotite	20-200
		Delmar sand	Greenish, gray, purple, red sands and sandy shale; some thin beds composed almost wholly of *Ostrea idriaensis* Gabb	100
	Unconformity			
Cretaceous, Chico formation				

Neither the Delmar sand nor the Torrey sand appear to be exposed in the San Diego Pliocene basin southeast of Mission or False Bay, but they are well exposed in parts of the La Jolla Quadrangle to the north. The base of the Delmar sand is nowhere exposed in the area studied by Hanna though it is possible it may be exposed farther north and its equivalent may outcrop along the shore just north

[138] "?*A*[*mmonites*]. *Cooperii*, n.s." Gabb, Geol. Surv. Calif., Palaeo., Vol. 1, p. 69, pl. 14, figs. 23, 23a, 1864. This species is referable to some genus with ornamentation similar to that of *Anisoceras* Pictet.

[139] Wadleigh's Map of the City of San Diego, San Diego County, Calif. C. B. Wadleigh, Publisher, 913 Fifth Street. Scale 4 inches to the mile. Copyrighted 1888. Lith. by Los Angeles Lith. Co., 48 and 52 Banning Street, Los Angeles, Calif. This map was called to our attention by Mr. John Davidson, Curator of the Junipero Serra Museum, San Diego Historical Society.

[140] Hanna, M. A., "Geology of the La Jolla Quadrangle, California," Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, no. 7, pp. 187-246, pls. 17-23, 1 map, Nov. 20, 1926. See especially pp. 189-191. The paleontology of the Eocene of this quadrangle by the same author is entitled "An Eocene Invertebrate Fauna from the La Jolla Quadrangle, California," and is no. 8 in the same bulletin, pp. 247-398, pls. 24-57, March 25, 1927. — See also, Cushman, J. A., and Hanna, M., "Foraminifera from the Eocene near San Diego, California," Trans. San Diego Soc. Nat. Hist., Vol. 5, no. 4, pp. 45-64, pls. 4-6, March 15, 1927. — See also, Hertlein, L. G., and Grant, IV, U. S., Calif. Journ. Mines and Geol., Vol. 35, no. 1, 35th Rept. Calif State Mineralogist, pp. 65-68, Jan., 1939 [received at library of the California Academy of Sciences, Aug. 23, 1939].

of the Pacific Beach Pliocene section where it overlies the Cretaceous. As pointed out by Hanna,[141] this lowest member of the La Jolla formation was apparently deposited in a shallow brackish water embayment. The most common species, *Ostrea idriaensis* Gabb, *Potamides carbonicola* Cooper and *Unio* (?) *torreyensis* M. A. Hanna, together with mud-flat sediments alternating with cross-bedded and rapidly lensing layers, are features confirming Hanna's opinion. The peculiar greenish hue of much of the Delmar is also similar to certain other known brackish water deposits. This brackish water facies is most prominent towards the top of the Delmar where layers of fossil leaves are occasionally found. In the lower part of the formation as exposed, particularly along the beach at the foot of Torrey Pines Grade, the sediments have a more normal marine facies. It is in these more normal marine lower beds that most of the 32 species listed by Hanna occur. According to Hanna, "With the exception of four species, all of the 32 species determined from the Delmar sand were present in the Rose Cañon shale. These four species were not found to be abundant in the Delmar sand. Because of these data it is believed the Delmar sand and the Rose Cañon shale constitute a unit faunally, although a difference in salinity of the water and possibly a period of elevation separated the deposition of the two, as is shown by the Torrey sand." The preservation of the Delmar fossils is on the whole very poor and the total fauna is no doubt much larger than the 32 species determined by Hanna. Recent detailed studies of the Eocene, chiefly by Mr. Frank B. Tolman and by Professor B. L. Clark and his students, have shown that it is possible to recognize a larger number of faunal horizons than was known at the time Hanna's paper was published, and on the basis of these recent data, the Delmar would be differentiated faunally from the Rose Canyon shale faunas.

When in superposition the Torrey sand is in gradational contact with the underlying Delmar. However, in at least one place, the Torrey sand is seen to rest with marked unconformity on the Black Mountain volcanics, indicating an overlap of the Delmar by the Torrey to the east. It is well exposed sometimes in castellated erosional[142] remnants high up on the hillsides in the general vicinity of the mouth of Soledad Canyon south of Del Mar.

While not explicitly stated by Marcus Hanna, the Torrey sand, from its coarse-grained, cross-bedded, and sometimes reddish colored character, together with the almost total absence of marine fossils, has generally been considered non-marine. That this is at least in part not the case is shown by the presence of limonitized outlines of marine pelecypod casts in exposures back of the beach at the foot of Torrey Pines Grade. Also, a marine shale stratum in the middle of the Torrey sand has been exposed by recent excavating along the new Torrey Pines Grade. It is probable that the Torrey sand indicates a succession of geomorphic events in the crystalline area to the east somewhat similar to that indicated by the quartz sand zone of the Ione formation in the foothills of the Sierra Nevada in eastern central California. In the latter case an uplift of the peneplained Sierras was responsible for the deposition in the coastal lowlands of glass sand, coal and pottery clay with anauxite between Capay and Domengine times. This was pointed out in a paper presented by Mr. F. B. Tolman.[143] From Mr. Tolman's interpretations it follows that the Delmar may correspond in age to some part of the Capay formation and the Torrey sand to Ione or early Domengine time.

In much of the La Jolla Quadrangle the Rose Canyon shale lies conformably on the Torrey sand. Where the Torrey sand is absent the Rose Canyon rests unconformably on the Black Mountain volcanics or on the Cretaceous. Southward the Rose Canyon shale also appears to overlap the Torrey sand. While there is an undoubted unconformity between the La Jolla formation and the Cretaceous, the evidence seems to be indirect except where the Rose Canyon shale member rests nonconformably on the Cretaceous.

The Rose Canyon shale occurs under much of the Kearny or Linda Vista Mesa and also farther south where it underlies the San Diego Pliocene along the south side of Mission Valley. Most of the peninsula of Point Loma consists of Eocene overlying the Cretaceous, but the beds are not very fossiliferous in that area. A few fossils have been collected at the northeastern end of the peninsula,

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141 Hanna, M. A., Univ. Calif. Publ. Bull., Dept. Geol. Sci., Vol. 16, no. 8, p. 257, 1927.

142 Holder, C. F., "Pyramids of Del Mar—Erosion of the Pacific Coast," Sci. American, Vol. 85, p. 8, 3 figs., 1901. [Discusses badland effect of erosion at several localities along the Pacific coast].

143 Amer. Assoc. Petrol. Geol., 22nd Ann. Meeting, Los Angeles, Calif., March 17-19, 1937. Program, pp. 61-62.

which suggests the presence there of the Rose Canyon member of the La Jolla formation. As mentioned later in this paper the Rose Canyon fauna has been recognized in well samples from the region south of San Diego Bay, suggesting that the Rose Canyon shale may be widespread underlying the San Diego formation.

For a more complete list of the species occurring in the Rose Canyon shale the reader is referred to the paleontologic report of Marcus Hanna already mentioned. The following is a very abbreviated list of species reported by Hanna or discovered later by Tolman in the Rose Canyon member of the La Jolla Quadrangle: *Acila decisa* Conrad, *"Crassatellites" semidentata* Cooper, *Glycymeris rosecanyonensis* M. Hanna, *Macoma rosea* M. Hanna, *Nuculana parkei* Anderson and Hanna, *Calyptraea diegoana* Conrad, *Ectinochilus problematica* M. Hanna, *Ectinochilus canalifer supraplicatus* Gabb, *Pelecyora aequilateralis* Gabb, *"Surcula" lindavistaensis* M. Hanna, *"Surcula" praeattenuata* Gabb, *Turritella applini* M. Hanna, *Turritella scrippsensis* M. Hanna, *Turritella soledadensis* M. Hanna, *Aturia myrli* M. Hanna, *Eutrephoceras hannai* Vokes, *"Flabellum" sandiegoensis* M. Hanna. In addition to these megafossils Mr. F. B. Tolman has collected *Discocyclina cloptoni* Vaughan, and Dr. H. G. Schenck has reported *Discocyclina clarki* Cushman in the Rose Canyon shale.[144]

The Poway conglomerate, which overlies the La Jolla formation, consists chiefly of conglomerates with occasional lenses of cross-bedded sand. Gray shale lenses containing fossils occur in the lower three hundred feet and considerable soft white chalky caliche is present in the upper part. According to Hanna the Poway is in places conformable with the Rose Canyon shale but in other places an erosional unconformity can be seen. Eastward it rests with marked unconformity on the Black Mountain volcanics. Well records indicate that the Poway reaches a thickness of at least 875 feet.

A few fossils have been found in interbedded marine sediments in the Poway conglomerate. Marcus Hanna reported the following species: *Acila lajollaensis* M. A. Hanna, *Brachidontes ornatus* Gabb, *Crassatellites mulates* M. A. Hanna, *Nuculana parkei* Anderson and Hanna, *Pholadomya murrayensis* M. A. Hanna, *Pteria* cf. *pellucida* Gabb, *Tellina tehachapi* Anderson and Hanna, *Calyptraea excentrica* Gabb, *Discohelix murrayensis* M. A. Hanna, *Ficopsis remondii* Gabb, *Ficus mammillatus* Gabb, *Turritella applini* M. A. Hanna, *Pseudoliva volutaeformis* Gabb. In addition to those given by M. A. Hanna, Dusenbury[145] has cited the following six species from the Poway: *Cardium brewerii* Gabb, *Ostrea idriaensis* Gabb, *Pitar uvasanus* Conrad, *Solen novacularis* Anderson and Hanna, *Conus remondii* Gabb, *Ectinochilus canalifer* Gabb. Dusenbury (p. 91), also gave a short list of foraminifera obtained from these beds.

Many years ago Fairbanks called what is now considered a part of the Poway conglomerate an ancient river gravel and traced high elevation gravels which he believed were extensions of it far to the east in the mountains of San Diego County. Much later Ellis and Lee included the Poway in the lower part of the San Diego formation. Hanna, however, found diagnostic Eocene fossils in shaly parts of the Poway, and during the winter of 1931 Mr. L. M. Huey of the staff of the San Diego Society of Natural History collected a small fauna from a freshly opened cut of the Fenton Materials Company's quarry in Murray Canyon on the north side of Mission Valley. Huey's locality, which has been visited by many collectors since, is near one of Marcus Hanna's original localities and in about the same part of the section stratigraphically. The Eocene age of at least the lower part of the Poway is now well established.

Within the last few years a number of specimens of fossil vertebrates have been collected from the Poway conglomerate north of La Mesa. These appear to indicate an upper Eocene age for this part of the Poway. Professor Chester Stock of the California Institute of Technology has studied these specimens and has prepared for us the following statement in regard to them:

"The small collection of specimens obtained by the San Diego Society of Natural History in an excavation for a cesspool north of La Mesa included several jaws and teeth of mammals definitely older than those known from the Tertiary of California. Among the forms recognized are a carnivore, presumably a creodont, an agrio-

144 Another orbitoidal foraminifer resembling (if not identical with) *Discocyclina psila* Woodring occurs in the Rose Canyon shale above *D. clarki* and ranges up into the *D. cloptoni* zone.

145 Dusenbury, Jr., A. N., "A Faunule from the Poway Conglomerate, upper Middle Eocene of San Diego County California," Micropaleontology Bull., Vol. 3, no. 3, pp. 84-95, 2 figs. [No. 2 unnumbered], June 15, 1932. (Published by advanced students of Micropaleontology at Stanford University, Calif. Printed by Edwards Bros., Inc., Ann Arbor, Michigan).

choerid, and a tiny insectivore. Unfortunately the carnivore specimen is too imperfectly preserved to permit definite identification as to genus and species. The agriochoerid and the insectivore resemble comparable types in the Sespe upper Eocene of Ventura County. Since this collection was made, a few additional specimens have been obtained from the Poway in the vicinity of San Diego, the most important of which is a titanothere. The latter, determined on the basis of a skull fragment with teeth, is tentatively referred to the upper Eocene genus *Metarhinus*. A survey of the fossil mammals from the Poway suggests an upper Eocene age and a faunal stage earlier in time than that recorded from the upper Eocene of the Sespe."

Much of the Poway contains no fossils and appears to be of continental rather than marine origin and in this respect recalls the Sespe formation of the Ventura basin and other regions to the north.

The Ballena placer workings[146] for the recovery of gold east of Ramona in parts of sections 17, 18, 19, 20 and 21 of T. 13 S., R. 2 E., S. B. B. and M., are operated in gravels referred to the Poway conglomerate by Donnelly.[147] Although Donnelly stated that these gravels were marine, we agree with Fairbanks' conclusion that they represent a fluviatile deposit.

Although the Eocene is not known in surface exposures in the San Diego Quadrangle south and southeast of Balboa Park, some of the wells drilled in the south bay region have penetrated Eocene strata. Through the kind cooperation of Mr. J. E. Pettijohn, we have had access to the geological reports of George H. Doane on the San Diego Gas and Petroleum Corporation's Holderness No. 1 Well in the southeast quarter of section 32, Township 18 S., Range 2 West, San Bernardino Base and Meridian, near the mouth of the Tia Juana River. This well penetrated over a thousand feet of Eocene shales, sandstones and conglomerates, some of which contained diagnostic Eocene fossils.[148] According to Mr. Doane, *Discocyclina clarki* Cushman was found in the cores from 2,946-2,959 feet and 3,286-3,289 feet. In cores from 3,195-3,289 feet *Eosolen novacularis* Anderson and Hanna was obtained and *Cyclinella bunkeri* M. Hanna occurred between 3,286 and 3,289 feet. Between 3,289 and 3,324 feet the following were identified: *"Flabellum" sandiegoensis* M. Hanna, *"Tellina"* cf. *scrippsensis* M. Hanna (young), *"Cardium" sorrentoensis* M. Hanna, *Corbula cliffensis* M. Hanna, *Turritella applini* M. Hanna, *Acila decisa* Conrad and *"Cardita" sandiegoensis* M. Hanna. These fossils indicate the presence of the Rose Canyon member of the La Jolla formation. In three horizons between 4,498 and 4,795 feet *Baculites chicoensis* Trask was identified. This species is characteristic of the Cretaceous. Dr. G. D. Hanna and C. C. Church have furnished us a report on a core of this well from a depth of 3,706 feet as follows: "Gray, sandy, micaceous shale with abundant carbonized plant remains, shell impressions and foraminifera: *Cibicides* sp., *Eponides mexicana* Cushman, *Robulus inornatus* d'Orbigny, *Robulus mexicanus* var. *nudicostatus* Cushman & Hanna, *Siphonina* cf. *jacksonensis* Cushman & Applin. Eocene. Domengine." It is likely that the Eocene is widespread below the San Diego formation in the region south of the San Diego River Valley but is overlapped by the Pliocene eastward.

From time to time attempts have been made to obtain coal in the San Diego region. It is now impossible to locate accurately these reported carbonaceous deposits, but some of the coal beds have been reported in localities where Eocene strata are exposed at the surface. Tyson,[149] in 1850, stated: "It had been reiterated over and over again in letters, newspapers, and in other ways, that there was, a few miles north of this port, near the seashore, a coal formation capable of furnishing ample supplies of the 'best of coal for steamers' and other purposes. These beds prove to be layers of bitumen an inch or two thick, alternating with thin strata of small gravel and sand." Many years ago the San Diego Herald,[150] published in San Diego, stated (1856) that coal was found on Lewis Rose's ranch about five miles from town. According to this paper, prospectors on Rose's ranch dug to a depth of

146 Fairbanks, H. W., Calif. State Mining Bureau, 11th Ann. Rept. State Mineralogist, Vol. 11, p. 91, 1893. — Merrill, F. J. H., Calif. State Min. Bureau, 14th Ann. Rept. State Mineralogist, p. 652, 1916. Issued as a separate Dec., 1914.

147 Donnelly, M., Calif. Journ. Mines and Geol., Calif. State Mining Bureau, 30th Rept. State Mineralogist, Vol. 30, no. 4, p. 369, Oct., 1934.

148 The column, as constructed by George H. Doane from a study of the cores and ditch samples, is included in the present report under the treatment of the San Diego formation.

149 Tyson, P. T., "Geology and Industrial Resources of California," Senate Ex. Doc. 47, 31st Congress, 1st Session, 1850 (reprinted with an introduction, published by Wm. Minifie and Co., Baltimore, 1851), p. 20.

150 The San Diego Herald, Vol. 6, June 28, 1856, p. 2, col. 1.

120 feet. Later The Daily World,[151] also published at San Diego, contained a notice (1872) of a meeting of the owners of the "Soledad Coal Mines." These mines are said to have been located in Rose Canyon. The type locality of the Rose Canyon shale of Eocene age is at the bend of Rose Canyon. Old records indicate that a coal mine once existed a few miles farther north somewhere near the present location of the town of Del Mar. This is shown on a manuscript map[152] drawn in 1850 by Lieutenant Cave Johnson Couts of the First Dragoons, U. S. Army.

The lignitic Delmar member of the La Jolla formation exposed at the base of the beach bluff at Torrey Pines on the south side of the mouth of Soledad Canyon was briefly described in 1857 by William H. Emory, then Major, First Cavalry, and United States Boundary Commissioner.[153] Probably the Del Mar coal mine was an attempt to obtain coal of commercial value from this Delmar member of the La Jolla formation although we did not attempt to locate the exact position of this mine.[154] Merrill[155] discussed the occurrence of coal near Del Mar in his report on the mineral resources of San Diego County. Eocene rocks are exposed in this area, as shown on the map by Marcus Hanna. The coal reported in a boring at La Jolla occurred in Cretaceous rocks, according to Fairbanks.[156]

Inasmuch as some of the Eocene sandstones are similar in general field appearance to some facies of the Pliocene sands, we include here a sedimentary analysis of an Eocene sample for comparison. This analysis has been made for us by Dr. Gordon A. Macdonald.

No. 14. Eocene lithologic sample: north side of gully just north of Mercy Hospital on 6th Avenue Grade to Mission Valley. Ten feet below conglomerate. L. G. Hertlein and U. S. Grant, IV, collectors. August 12, 1937.

LIGHT MINERALS:

Quartz	54.9%
Orthoclase	25.0%
Oligoclase	15.0%
Albite	4.0%
HEAVY MINERALS:	1.1%

Magnetite—very rare
Ilmenite—moderately abundant
Epidote—abundant
Zoisite—abundant
Pink garnet—rather rare
Titanite—rather rare
Andalusite—rare
Zircon—rare
Piedmontite—rather rare

"The grains vary from .05 to ca. .4 mm. in diameter, and average ca. .2 mm. They are largely angular, but some are subangular. The sorting is rather good. The orthoclase feldspar is considerably kaolinized.

"This Eocene sample is very unusual, in that the heavy fraction is made up very largely of epidote and

[151] The Daily World, Vol. 1, no. 73, Oct. 16, 1872 [on unnumbered p. 3]. This reference was called to our attention by Mr. John Davidson, Curator of the Junípero Serra Museum of the San Diego Historical Society.

[152] This map was shown to us by Mr. Cave J. Couts of the Guajome Rancho, near Oceanside, San Diego County, son of the author of the map. A reproduction of this map was included by Fr. Zephyrin Engelhardt in his work "The Missions and Missionaries of California," New Series, Local history, San Luis Rey Mission, (San Francisco, California, 1921), p. 257.

[153] Rept. United States and Mexican Boundary Surv., Vol. 1, pt. 2, p. 90, and text figure on p. 85, 1857. Emory stated that the lignite was not of economic importance.

[154] Most if not all of the reports of the occurrence of "coal" in the San Diego region are based upon the existence of bituminous beds in the Eocene or the Cretaceous. Many years ago Goodyear reported "coal" 'and "slate rock with some coal" at, respectively, 177 feet and 245 feet depths in a well which had been sunk for the purpose of securing artesian water "on the east side of the bay, at a point where the mouth of the well was ninety-four and one-half feet above high water." From the text Goodyear appears to refer to San Diego Bay. If this is correct the well must have been in the Pliocene or in a deposit of later age. If he had been referring to Mission Bay instead of San Diego Bay the well could have been in the Eocene. See Goodyear, W. A., Calif. State Mining Bureau, 8th Ann. Rept. State Mineralogist, p. 518, 1888.

[155] Merrill, F. J. H., Calif. State Mining Bureau, 14th Rept. State Mineralogist, p. 713, July, 1915 (1916). Also issued as a separate, "Geology and Mineral Resources of San Diego and Imperial Counties," Dec., 1914, p. 83. "Lignite seams of limited thickness and extent have been reported from borings in the vicinity of San Diego, and tradition says that some thirty years ago a bed of coal exposed at low-water mark, in the beach near Del Mar, was worked as a source of fuel for blacksmith forges."

[156] Fairbanks, H. W., Calif. State Mining Bureau, 11th Ann. Rept. State Mineralogist, Vol. 11, p. 96, 1893.

zoisite, with a little of the rare mineral piedmontite. The fact that the only minerals left in the heavy fraction are of types which are resistant to chemical decomposition suggests that the Eocene may have been a time of pronounced chemical weathering. This of course corresponds well with the known character of the Ione and Capay sands. However, it is risky to attempt any conclusions on the basis of a single sample. The fact that the feldspar is still recognizable in this sample, although somewhat kaolinized, suggests that conditions were less severe than in the case of the Ione, or, which would bring about the same result, that erosion was more rapid in the San Diego region than in the source areas of the Ione." (G. A. Macdonald).

At several localities in the coastal region between Rose Canyon and Carlsbad, Eocene shales and clays are of suitable quality for the manufacture of brick, tile and pottery. For many years brick has been manufactured in Rose Canyon. At the present time the Union Brick Company operates on about 100 acres in this canyon. The Vitrified Products Corporation of Old Town controls clay properties five miles northeast of Cardiff and also two miles north of Linda Vista. The Pacific Clay Products Company of Los Angeles controls about thirty-five acres on the Agua Hedionda Land Grant near Carlsbad. All of these properties are benefited by good transportation facilities afforded by the Santa Fe Railroad and the paved highways.

ABSENCE OF OLIGOCENE AND MIOCENE ROCKS IN THE SAN DIEGO REGION

Oligocene sediments are absent in the San Diego region so far as now known. There are no sediments present between the Eocene and Pliocene at any of the known localities in that area and no Oligocene fauna has been reported in the extreme southern part of the State.

Miocene sediments are likewise absent in the area under discussion. In 1909 Tempère and Peragallo[157] listed 75 species of diatoms from "San Diego-Californie (États-Unis) Dépôt fossile marin." A careful examination of this list shows that the material undoubtedly came from some California locality of upper Miocene (Monterey) age. It was probably transmitted to Paris by some microscopist to whom the beauty of the fossils was appealing and the need of exact locality data was not apparent. The material may have come from any one of a great many known exposures, but probably was obtained somewhere in the vicinity of Capistrano where beds of the same age do outcrop. Many years ago C. R. Orcutt[158] reported "a specimen of diatomaceous earth from the ocean beach near San Diego." It was stated that this specimen was "very like some samples of the Redondo Beach deposit, and may have been washed from there." Orcutt's specimen undoubtedly came from a source nearer than Redondo, perhaps from the vicinity of Capistrano. North of Capistrano, beds of Vaqueros age containing the *Turritella inezana* fauna have been reported by Woodford.[159] Beds of Temblor age also occur in the north but they are likewise lacking in the area under discussion.

Blake and Conrad appear to be responsible for an early report of the presence of Miocene strata in the San Diego region. In Volume 5 of the U. S. Pacific Railway Reports, Blake stated:[160] "Before leaving the Mission of San Diego, a block of sandstone, filled with fossils, was handed to me, but the locality was not seen. It is a compact sandstone, not unlike that of the Bay of San Francisco and Oregon. Mr. Conrad finds it to contain the following species: *Cardium modestum, Nucula decisa, Corbula Diegoana, Mactra Diegoana, Natica Diegoana, Trochita Diegoana, Tellina Diegoana,* and *T. congesta.* He also remarks a palaeontological relation between these fossils and those of Monterey, Carmello, and those found in boulders in Oregon by Mr. Townsend and Professor Dana." These species were described by Conrad in an Appendix of the same volume[161] under the heading: "Fossils

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157 Tempère, J., and Peragallo, H., "Diatomées du Monde Entier," Ed. 2, pp. 160-161, 1907-1915. [These pages issued in 1909]. See also edition 1 (Paris), 1889-1895, pp. 271-272. Dr. G. D. Hanna kindly called these references to the attention of the authors. See Hanna, G. D., Bull. de la Soc. Franc. de Microscopie, Vol. 5, no. 3, p. 110, 1936.

158 Orcutt, C. R., West Amer. Sci., Vol. 7, whole no. 57, p. 136, Feb., 1891.

159 Woodford, A. O., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 15, no. 7, pp. 178-180, 1925.

160 Blake, W. P., U. S. Senate Ex. Doc. 78, and House of Representatives, Ex. Doc. 91, 33rd Congress, 2nd Session, "Reports of Explorations and Surveys to Ascertain the Most Practicable and Economical Route for a Railroad from the Mississippi River to the Pacific Ocean," etc., Vol. 5, pt. 2, Geological Rept., chap. 13, p. 176, 1857.

161 See pages 322-327. These species were actually first described without figures in House Doc. 129, Projected Vol. 3, 33rd Congress, 1st Session, 1855, Ap. to Report of W. P. Blake, pp. 11-18.

of the Miocene and Recent Formations of California." These species are now known to be Eocene fossils with the exception of *"Tellina" congesta,* the type of which is said to have come from the Miocene Monterey shale near Monterey, California.[162]

Ellis[163] mentioned some fossils collected in south Las Choyas Valley which Dall determined as "upper Miocene or probably Pliocene." Other fossils collected about 3¼ miles east of Chula Vista in a canyon locally known as Fossil Canyon, were determined by Dall to be of upper Miocene age, according to Ellis (p. 63). This latter locality is a well known Pliocene fossil bed from which the present authors have collected a small but distinctly Pliocene fauna.

Merrill[164] in 1914 pointed out that beds of middle Miocene age, which are the chief source rocks of oil in the San Joaquin Valley and Orange County, California, are lacking in San Diego County and that the deepest wells drilled have passed through the Tertiary and Cretaceous strata and penetrated a black shale, sometimes calcareous, which he suggested was probably of Jurassic age, although no faunal evidence for that age is known. Asphalt reported along the coast was considered to have come from long distances and not from the region about San Diego. Merrill's report indicated that there is but little chance for petroleum to be found in San Diego County and pointed out that drilling, while laudable as evincing a cordial public spirit, should only be undertaken by people or companies able to stand a loss, due to the fact that the possibility of finding oil in commercial quantities is slight. The present authors are inclined to agree with Merrill's conclusion.

The logs of a number of wells which have been dug or drilled in the San Diego region have been given by Ellis[165] in his report on the water resources of western San Diego County, and by the present authors in a recent paper.[166] Some of these well logs are mentioned briefly in the present paper in the discussion of the Cretaceous and of the Pliocene.

PLIOCENE

In 1874 W. H. Dall[167] listed and discussed the fossil mollusks collected by Henry Hemphill from the material removed in digging a well for water in San Diego. The well was located near the mouth of what is now known as Cabrillo Canyon in Balboa Park. Although this well has long since been filled in, the brick lining of the mouth of the well can still be seen at the date of this writing (October, 1939) in a grassy swale near two eucalyptus trees. It is located "on the northerly prolongation of the east line of Eleventh Avenue, 85 feet north from the easterly production of the north line of Beech Street."[168] The elevation of the ground at the well-head is approximately 96 feet above mean sea level and as the well was stated to have attained a depth of 160 feet, the bottom was considerably below sea level. The mouth of the well is brick-lined and has a diameter of about 10½ feet. The location of the well is shown on the contour map (text figure 1a) and the sequence of some of the fossil beds penetrated by the well are shown in the accompanying cross section (text figure 1b). Although the strata encountered in the well were said to be fossiliferous throughout, the lower beds, from which Dall stated most of his specimens came, were not discovered by us outcropping in the immediate environs of the well. The large scale one-foot contour interval map of Balboa Park in the City Engineer's Office and a recent Transit survey determine the dip of the beds in the vicinity of the well to be 4°, in a direction south 33° 30′ west. If the dip and strike of the beds remain constant, the fossiliferous strata at the bottom of the well might be expected to outcrop in the bottom of Cabrillo Canyon between Juniper and Laurel Streets projected.

Dall concluded that the age of the fossils obtained from the well was Pliocene. This was the

162 Schuchert, Charles, assisted by Dall, W. H., Stanton, T. W., and Bassler, R. S., U. S. Nat. Mus., Bull. 53, Pt. 1, p. 643, 1905. According to Dall (U. S. Geol. Surv., Prof. Paper 59, p. 126, 1909) this species appears to be a *Macoma.* The San Diego Eocene species to which the name *congesta* was erroneously applied by Conrad, is not known to the present authors.

163 Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, p. 62, 1919.

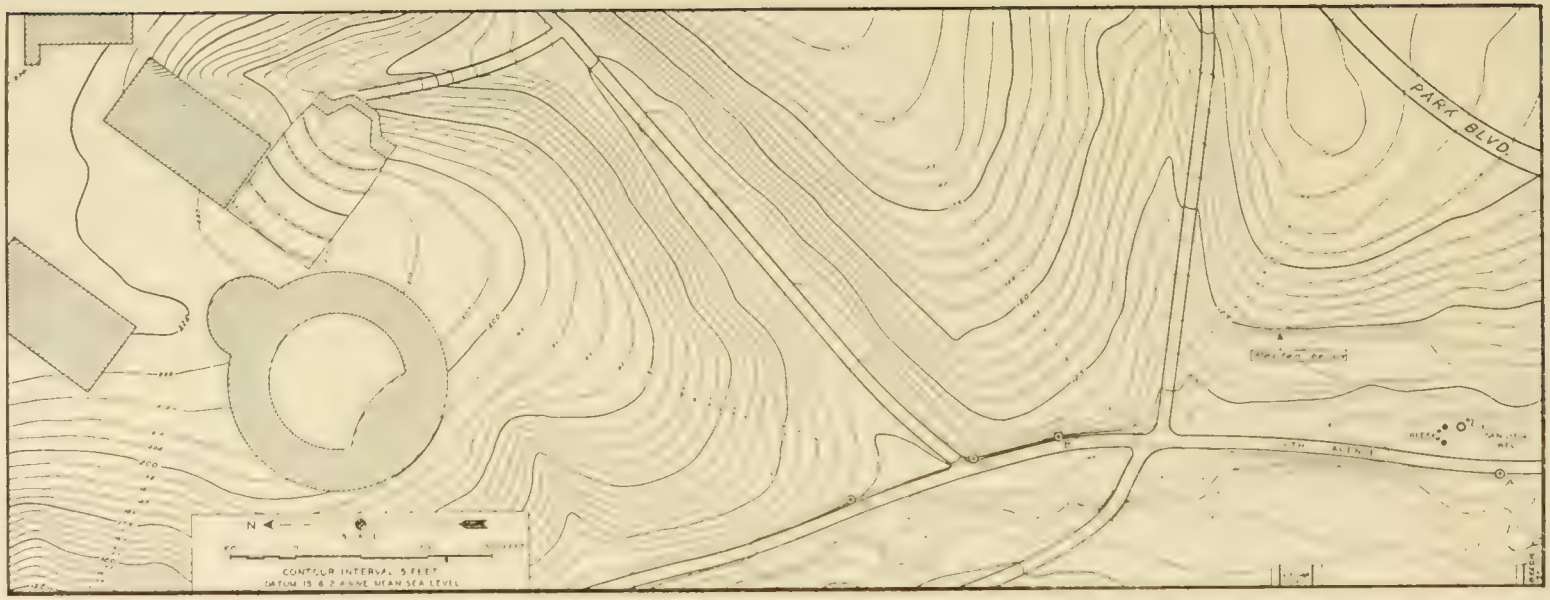
164 Merrill, F. J. H., Calif. State Mining Bureau, Bull. 69, pp. 467-468, 1916. Issued as a separate Dec., 1914.

165 Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv. Water Supply Paper 446, pp. 55-68, 1919.

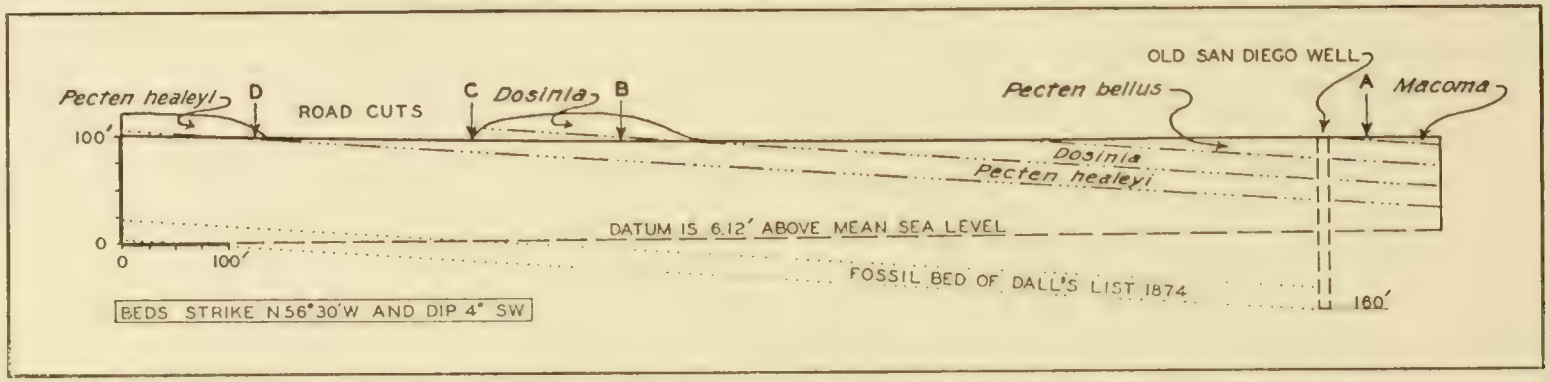
166 Hertlein, L. G., and Grant, IV, U. S., Calif. Journ. Mines and Geol., Vol. 35, no. 1, 35th Rept. Calif. State Mineralogist, pp. 74-77, Jan., 1939, [received at library of the California Academy of Sciences Aug. 23, 1939].

167 Dall, W. H., Proc. Calif. Acad. Sci., Vol. 5, pp. 296-299, 1874.

168 Data from H. W. Jorgensen, City Engineer of San Diego, letter of April 7, 1939.



TEXT FIG. 1a. Contour map of a portion of the southern part of Balboa Park, showing the location of the old San Diego well and the line of the section shown in text figure 1b.



TEXT FIG. 1b. Section of Pliocene strata from near the old San Diego well in Balboa Park northward, as indicated on the contour map, text figure 1a. This shows the local sequence of fossiliferous beds and the position of the well projected into the section.

first faunal assemblage of any size in California to be definitely placed in the Pliocene, and hence that locality is one of the early well-defined Pliocene localities of the State. As Dall's early paper is now becoming quite rare, we reproduce below the list of fossils exactly as given by Dall together with what we consider are the proper names of the species represented, in modern nomenclature, in the column at the right.

EXACT COPY OF ORIGINAL LIST	PROBABLE EQUIVALENT IN MODERN NOMENCLATURE
P. 296	
" 1. *Glottidia albida,* Dall ex Hinds."	*Glottidia albida* Hinds
" 2. *Xylotrya,* sp. indet. Tube only."	*Xylotrya* sp.
" 3. *Cryptomya Californica,* Conr."	*Cryptomya californica* Conrad
" 4. *Solen rosaceus,* Cpr."	*Solen rosaceus* Carpenter
" 5. *Solecurtus Californianus,* Conr."	*Tagelus californianus* Conrad
" 6. *Macoma* (var.?) *expansa,* Cpr."	*Tellina expansa* Carpenter or *Tellina* (*Oudaria*) *buttoni* Dall
" 7. *Callista,* sp. indet. Smooth, inflated, thin; much like *Callista Newcombiana,* erroneously described as *Lioconcha* by Gabb."	*?Compsomyax subdiaphana* Carpenter
P. 297	
" 8. *Cardium centifilosum,* Cpr."	*Nemocardium centifilosum* Carpenter
" 9. *Venericardia borealis,* Conr."	*Cardita* (*Cyclocardia*) *ventricosa* Gould
"10. *Lucina nuttallii,* Conr."	*Lucina* (*Lucinisca*) *nuttalli* Conrad
"11. *Lucina borealis,* Linn."	*Lucina* (*Lucinoma*) *annulata* Reeve
"12. *Lucina tenuisculpta,* Cpr."	*Lucina* (*Parvilucina*) *tenuisculpta* Carpenter
"13. *Cryptodon flexuosus,* Mont."	*Thyasira gouldii* Philippi
"14. *Modiola recta,* Conr."	*Volsella* [=*Modiolus*] *recta* Conrad
"15. *Arca microdonta,* Conr."	*Arca trilineata* Conrad
"16. *Nucula,* sp. n. according to Dr. Cooper; named in MSS. by Carpenter. Looks much like *N. tenuis.*"	*Nucula exigua* Sowerby
"17. *Acila Lyallii,* Baird. This species has been frequently reported as *castrensis,* Hds."	*Acila castrensis* Hinds
"18. *Leda coelata,* Hinds."	*Nuculana taphria* Dall
"19. *Pecten hastatus,* Sby."	*Pecten* (*Chlamys*) *hastatus* Sowerby
"20. *Amusium caurinum,* Gld."	*Pecten* (*Patinopecten*) *healeyi* Arnold
"21. *Janira florida,* Hds."	*Pecten* (*Pecten*) *stearnsii* Dall
"22. *Ostrea conchaphila,* Cpr."	*Ostrea conchaphila* Carpenter
"23. *Placunanomia macroschisma,* Desh."	*Pododesmus macrochismus* Deshayes
"24. *Tornatina eximia,* Baird."	*Acteocina eximia* Baird
"25. *Cylichna cylindracea,* Linn."	*Cylichnella alba* Brown
"26. *Dentalium hexagonum,* Sby."	*Dentalium neohexagonum* Sharp and Pilsbry
"27. *Dentalium semipolitum,* B. and S."	*Dentalium semipolitum* Broderip and Sowerby
"28. *Siphonodentalium pusillum* (?), Gabb."	*Cadulus fusiformis* Pilsbry and Sharp
"29. *Calliostoma annulatum,* Mart."	*Calliostoma annulatum* Martyn
"30. *Galerus filosus,* Gabb, as *Trochita.*"	*Calyptraea* (*Trochita*) *filosa* Gabb
"31. *Crepidula navicelloides,* Nutt."	*Crepidula nummaria* Gould
"32. *Crepidula princeps,* Conr. This is not *grandis* of Midd."	*Crepidula princeps* Conrad
"33. *Turritella Jewettii,* Cpr."	*Turritella jewettii* Carpenter
"34. *Bittium asperum,* Cpr."	*Bittium* (*Lirobittium*) *asperum* Gabb
"35. *Myurella simplex,* Cpr."	*Terebra martini* English
"36-39. *Drillia,* sp. indet. This and three other forms of *Drillia* so closely resemble Gulf forms, that it is inadvisable to describe them without a comparison of specimens."	? Possibly *Clathrodrillia,* four new species
"40. *Surcula Carpenteriana,* Gabb, and variety *Tryoniana,* can hardly be separated as species. The transition is very gradual and complete."	*Megasurcula carpenteriana* Gabb
"41. *Mangelia variegata,* Cpr."	*Mangelia barbarensis* I. S. Oldroyd
"42-45. *Mangelia,* spp. indet. The same remark applies here as to No. 36."	? Possibly *Mangelia* n. sp., and others

EXACT COPY OF ORIGINAL LIST	PROBABLE EQUIVALENT IN MODERN NOMENCLATURE
"46. *Clathurella Conradiana,* Gabb. The specimens are slightly stouter than Gabb's figure, but vary among themselves in this respect, and in other characters are similar to his species."	*Glyphostoma conradiana* Gabb
"47. *Odostomia straminea,* Cpr. var."	*?Odostomia* (*Evalea*) *tenuisculpta* Carpenter
"48. *Odostomia,* sp. indet. Very imperfect."	*Odostomia* sp.
"49. *Chemnitzia torquata,* Cpr."	*?Turbonilla* (*Strioturbonilla*) *torquata* Carpenter
"50. *Eulima rutila,* Cpr."	*Melanella* (*Eulima*) *rutila* Carpenter or *Strombiformis riversi* Bartsch
"51. *Scalaria subcoronata,* Cpr."	Probably *Epitonium* (*Nitidiscala*) *tinctum* Carpenter
"52-55. *Cancellaria,* 4 spp. indet. Most of them, as far as memory serves, resemble southern forms not at hand for comparison."	Probably *Cancellaria arnoldi* Dall, *C. hemphilli* Dall, *C. crawfordiana* Dall, and *Cancellaria,* n. sp.
"56. *Neverita Recluziana,* Petit."	*Polinices* (*Neverita*) *reclusianus* Deshayes
P. 298	
"57. *Sigaretus debilis,* Gld."	*Sinum debile* Gould
"58. *Ranella Mathewsonii,* Gabb."	*Gyrineum lewisii* Carson
"59. *Olivella boetica,* Cpr."	*Olivella pedroana* Conrad
"60. *Nassa fossata,* Gld."	*Nassarius* (*Schizopyga*) *fossatus* Gould
"61. *Nassa mendica,* Gld."	*Nassarius* (*Schizopyga*) *mendicus* Gould
"62. *Astyris tuberosa,* Cpr."	*Mitrella tuberosa* Carpenter
"63. *Astyris,* sp. indet. jun."	*Mitrella* sp. or *Cosmioconcha* n. sp.
"64. *Ocinebra lurida,* Cpr."	*Ocenebra lurida* Middendorff
"65. *Pteronotus festivus,* Hinds."	*Triremis festiva* Hinds
"66. *Trophon orpheus,* Gld."	*Trophon* (*Boreotrophon*) *stuarti* E. A. Smith
"67. *Fusus* (*Colus*) *Dupetit-Thouarsi* ? Kien."	*Fusinus* (*Barbarofusus*) *?barbarensis* Trask
"68. *Chrysodomus,* n. s. Too imperfect for description, but very distinct; perhaps a *Volutopsis,* as the nucleus would indicate."	
"69. *Chrysodomus Diegoënsis,* n. s."	*Searlesia diegoënsis* Dall

Dall[169] later referred to the sediments from which the San Diego well fossils were obtained as the "San Diego Beds" and Arnold[170] referred to these fossiliferous sands as the "San Diego formation." Although Arnold[171] described in much greater detail the Pliocene sandstones of Pacific Beach and listed a considerable fauna from them, the San Diego well must be considered the type locality of the San Diego formation. This is unfortunate, since the historic well has long since been filled in and an outcrop of beds with an identical fauna has not yet been definitely located in the immediate environs. Due to the fact that the San Diego formation cannot readily be divided into members which can be recognized at different localities, it is entirely reasonable to include in the San Diego formation all the marine Pliocene sedimentary beds of the region, with the exception of the overlying reddish-brown conglomeratic sandstone which caps most of the mesas and which may be of late Pliocene or Pleistocene age.

The Pliocene exposed in the beach bluffs at Pacific Beach, however, may represent a higher part of the Pliocene than the *Trophosycon* beds exposed in the road cut below the Mercy Hospital and the Pliocene fine sands exposed along India Street. The Pacific Beach beds are not continuous in surface exposures with the Pliocene in the San Diego Mesa and with just what part of the latter the Pacific Beach beds correlate cannot be stated definitely now. Some of the older forms found in the mesa Pliocene, such as *Trophosycon,* have not yet been discovered at Pacific Beach.

DISTRIBUTION

Pliocene beds here referred to the San Diego formation compose the greater part of the mesa-

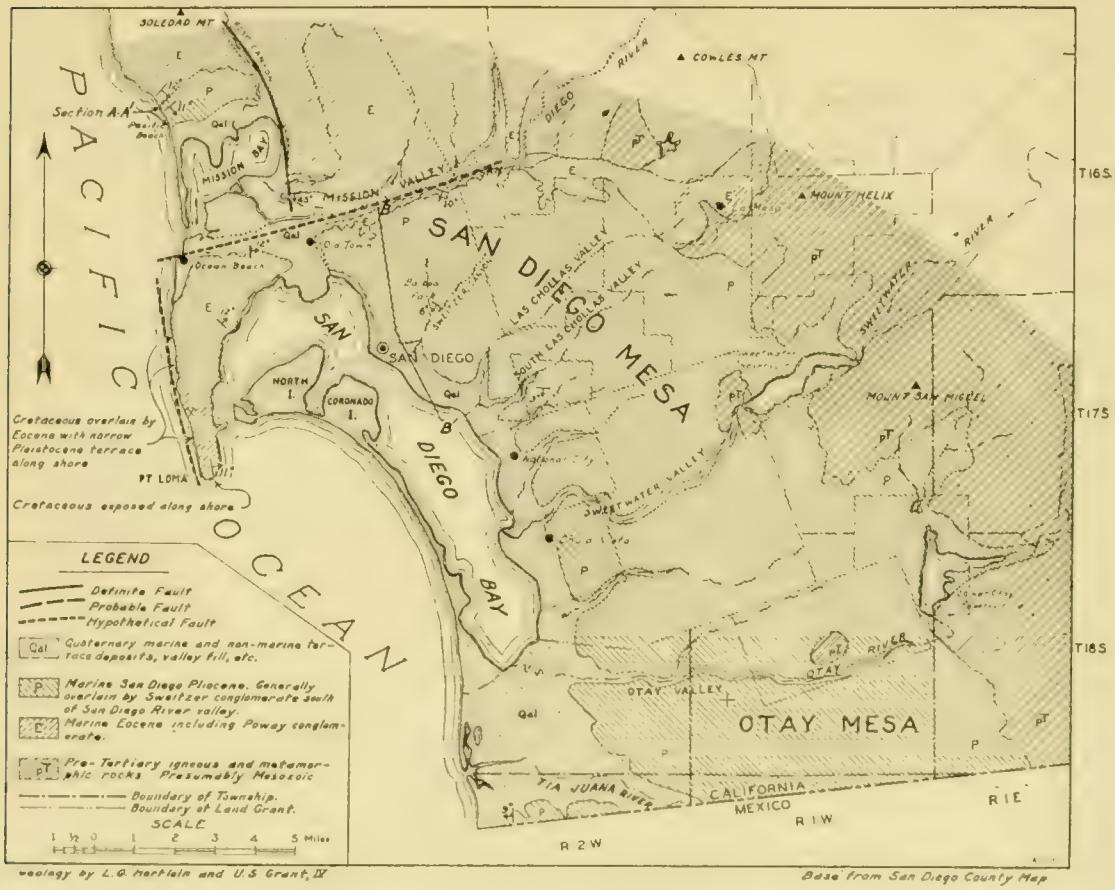
169 Dall, W. H., U. S. Geol. Surv., 18th Ann. Rept., Pt. 2, 1898, opp. p. 334, p. 337.

170 Arnold, R., Journ. Geol., Vol. 10, p. 130, 1902. According to Arnold the San Diego well was 149 feet deep.

171 Arnold, R., Mem. Calif. Acad. Sci., Vol. 3, pp. 57-58, 1903. — U. S. Geol. Surv., Prof. Paper 47, p. 28, 1906.

lands of the San Diego region, and cover a large area from the south slope of the San Diego River Valley to some distance beyond the Mexican Boundary. They also outcrop on the lower southern slopes of Mount Soledad and in the bluff behind the beach at Pacific Beach. No Pliocene is known to occur in the Linda Vista Mesa north of the San Diego River Valley nor on Point Loma.

The contact between the known Pliocene sediments and the Eocene and older rocks is indicated on the map (text figure 2). Over much of the region the Pliocene sandstones are covered by a mantle

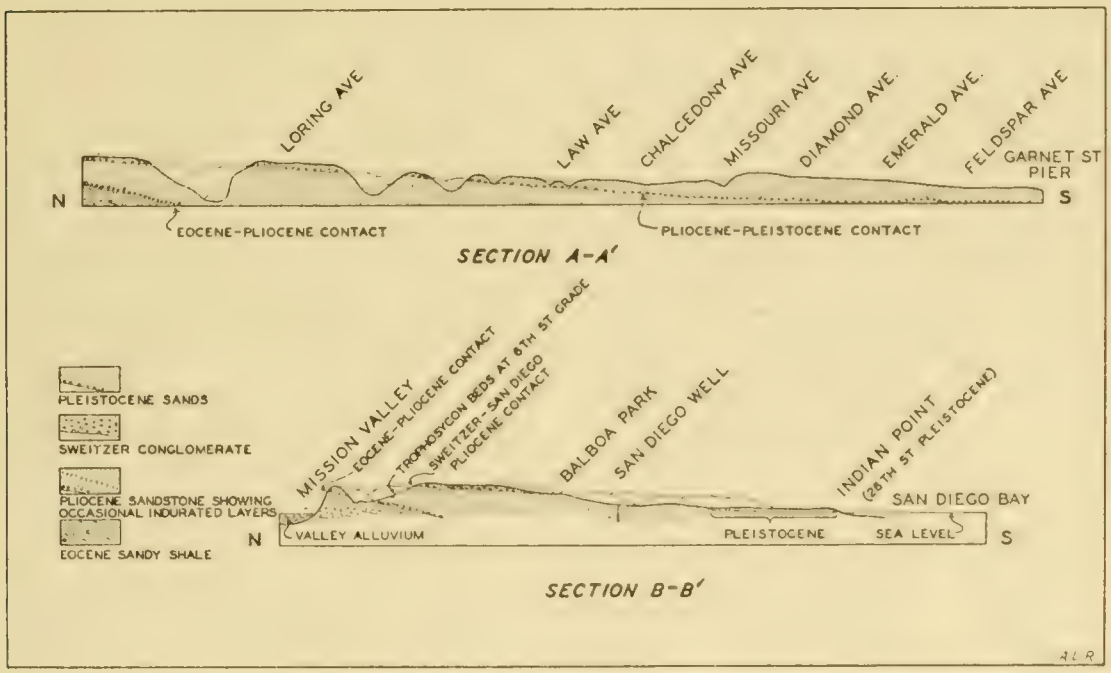


TEXT FIG. 2. Map of areal geology of the San Diego region. Quaternary sediments on the mesas and on some of the higher terraces have been omitted. To have included them all would obscure the true distribution of the older deposits. The small scale of this map has made it impracticable to attempt to delineate the distribution of the upper Cretaceous rocks exposed in the sea-cliffs along the southern half of Point Loma. Due to the scale, certain narrow Pleistocene terrace deposits which occur along the west shore of Point Loma have also been omitted. The intermittent streams have been emphasized to bring out the drainage direction and pattern. The mine symbol on the west side of Point Loma indicates the position of the "Coal Mine" which is about 1¾ miles north of the lighthouse at the end of Point Loma. The topography of this region is shown on U. S. Geological Survey Maps of the San Diego, La Jolla, Cuyamaca and El Cajon quadrangles.

of later terrace material and soil which has not been indicated on the map. A great part of the mesa south of the San Diego River Valley is capped by a characteristic reddish-brown conglomerate, which has been named the Sweitzer formation. Due to the limited time which could be devoted to field work and the small scale of the map, it has not been possible to plot the contact between the San Diego formation and the overlying Sweitzer formation. All of the Coronado peninsula, including North Island, the terrace upon which the business section of the City of San Diego has been built, the Pacific Beach-Crown Point Terrace, and the lower terraces east of the southern part of the San Diego Bay are of Pleistocene age as shown by numerous deposits of Pleistocene fossils.

LITHOLOGY AND SEDIMENTATION

Lithologically the San Diego formation consists of generally fine-grained sands of a bluish-grey to yellowish-brown color, with occasional layers and lenses of gravel. Where the sand is very fine-grained and of a light bluish-gray color, it is difficult to distinguish from some of the Eocene sandstones exposed just to the north of the Pliocene basin. Fine-grained sands, often micaceous, compose the bulk of the observed thickness of the San Diego formation, but locally it grades into coarser sand and occasionally gravel and lenses or layers of conglomerates. In the mesa on the south side of Tia Juana Valley, about one mile west of the Boundary School, a considerable thickness of conglomerates



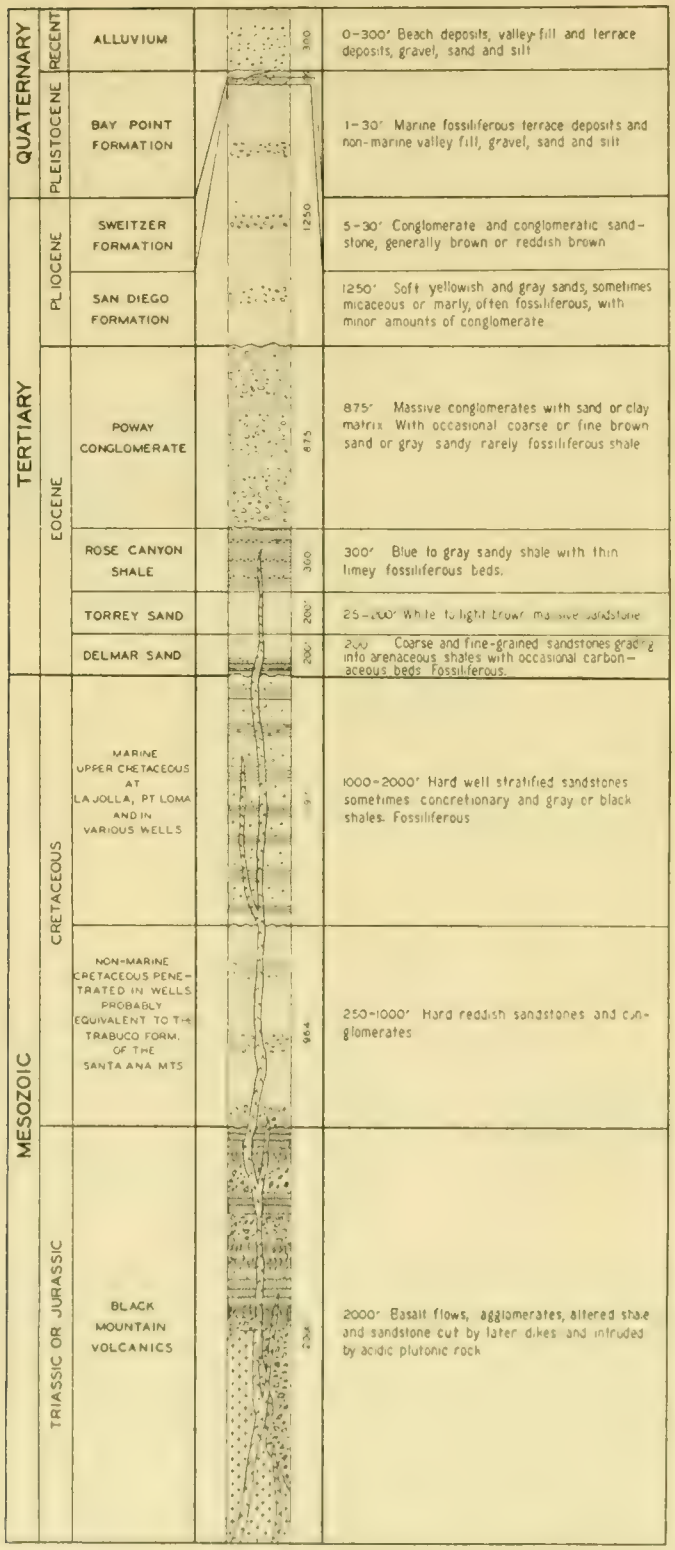
TEXT FIG. 3. Section A-A'. Generalized section of Pacific Beach Pliocene deposits as exposed in the bluff facing the beach. Total distance north to south about 3,850 feet. Vertical scale greatly exaggerated *Pecten healeyi* occurs most abundantly in the lower half of the beds exposed in this section. Beds in the upper half of the section contain abundant specimens of *Pecten bellus*.

Section B-B'. Diagrammatic sketch showing the relationships of the Pliocene San Diego formation to the Eocene, to the Sweitzer formation on Sixth Avenue, and to the Pleistocene. Section approximately north and south from Mission Grade to foot of 26th Street. Distance about 5 miles. Vertical scale greatly exaggerated.

The locations of the cross-sections are shown on the map in text figure 2.

and coarse indurated sands is exposed in a small steep canyon on the United States side of the Mexican Boundary. This conglomerate stratum is fully 100 feet thick, and the larger boulders range up to three feet in maximum diameter. The discovery of a Pliocene fossil locality not far to the west suggests that this conglomerate is also Pliocene in age and the equivalent of the San Diego formation of Otay Mesa and other Pliocene mesas farther north. The boulders are moderately well rounded and consist of hard dense crystalline rocks of varying colors. The source of the boulders may have been some of the nearby mountains just south of the Border in Lower California. Coarse-grained sandstones are uncommon in general in the San Diego formation but a prominent outcrop of very coarse-grained gravelly sandstone occurs in a spur between the two northeastern extensions of Paradise Valley, about three and a quarter miles west of Sweetwater Reservoir (Plate 10, figure 2).

The other lithologic extreme met with in the San Diego formation is represented by marly material which occurs in pockets or seams, and rarely in beds of nearly pure white marl. Due to the fact that much of the mesa region is mantled by soil which is effectively held in place, even on



TEXT FIG. 4. Columnar section of the rocks exposed in the southwestern part of San Diego County. This section, except the Cretaceous part, is compiled from observations of surface exposures of the rocks. The Cretaceous section is compiled from well logs.

the slopes, by brush and lichens, moss and small ferns, no estimate of the proportion, nor idea of the regularity in distribution of these chalky deposits could be obtained; but they appear to be more common in the eastern parts of the mesas. These marly deposits are exposed at several places in the eastern Otay region and on the edge of the mesa north of the upper reaches of Las Choyas Valley. It is possible that the thicker beds represent quieter and slower deposition on the leeward sides of projecting promontories of pre-Tertiary hard rock, some of which now form foothills in that district. The seams and pockets may be due to a concentration of limy material by percolating waters.

A dark colored bentonite bed eight inches to one foot thick occurs in the Pliocene yellowish-brown and gray sands exposed in a road cut on Federal Avenue about 400 feet east of 35th Street. During the construction of an elevator shaft at the east end of the Natural History Museum Building in Balboa Park in the spring of 1943, a stratum of volcanic ash was encountered which appears to be a water-laid bentonite and is the most northerly known occurrence of volcanic ash in the San Diego Pliocene. A sample was examined from the bottom of the shaft at a depth of 56 feet below the ground floor of the building. This would be at an elevation of approximately 232 feet above mean sea level. The general decrease in dip of the San Diego formation southeasterly from Balboa Park suggests that this bentonite may be at about the same stratigraphic position as the bentonite mentioned above which is exposed on Federal Avenue, several miles southeasterly from Balboa Park. The only other bentonite known to us in the Pliocene of this region is that which occurs on the north and south sides of Otay Valley. These bentonite beds are an exceptional phase of the lithology of the San Diego formation, which is characteristically fine sand.

The sediments of the San Diego formation, taken as a whole, represent deposits which have accumulated in relatively shallow water. The occasional cross-bedding, lenses and layers of conglomerate, and the lack of shale, all point to a depth of water from low tide to possibly fifty fathoms. This is borne out to a great extent by the fossils, including the Mollusca, Echini and Foraminifera. In this ecologic aspect the San Diego Pliocene is unlike equivalent horizons in the Los Angeles basin, other than the rare marginal shallow water facies.

Dr. Gordon A. Macdonald has made a petrographic study of samples of Pliocene sediments collected by us at several localities. His report on these sediments is included here.

No. 15. Pliocene. Road-cut S-SE of Mercy Hospital on 6th Avenue Grade to Mission Valley. This is above the *Trophosycon* beds. L. G. Hertlein and U. S. Grant, IV, collectors. August 12, 1937.

LIGHT MINERALS:

Quartz	41.8%
Orthoclase	29.9%
Oligoclase	19.9%
Albite	5.0%

HEAVY MINERALS: 3.4%

Magnetite—rare
Ilmenite—moderately abundant
Green hornblende—abundant
Actinolite—abundant
Epidote—moderately abundant
Zoisite—moderately abundant
Titanite—moderately abundant
Zircon—moderately abundant
Colorless garnet—moderately abundant
Glaucophane—rather rare
Brown biotite—rather rare
Brown hornblende—rather rare
Rutile—rare

"The grains are angular, with a few subangular. They vary from about .01 to .05 mm. in diameter, the average being about .02 mm. The sorting is good. The feldspar is largely unaltered." (G. A. Macdonald).

No. 16. Pliocene. Southeast corner of India and Upas Streets. One foot below fossil zone. L. G. Hertlein and U. S. Grant, IV, collectors. August 13, 1937.

LIGHT MINERALS:

Quartz	50.5%
Orthoclase	25.3%
Oligoclase	10.1%
Albite	2.0%
HEAVY MINERALS:	12.1%

Magnetite—rare
Ilmenite—moderately abundant
Green hornblende—abundant
Actinolite—moderately abundant
Titanite—moderately abundant
Zircon—moderately abundant
Epidote—rather rare
Zoisite—rather rare
Brown biotite—rather rare
Glaucophane—rare
Colorless garnet—rare
Rutile—rather rare
Brown hornblende—rare

"The grains range from about .005 to .03 mm. in diameter, averaging about .01 mm. The sorting is good. The grains are angular, and the feldspar is fresh." (G. A. Macdonald).

No. 17. Pliocene. Paradise Valley, San Diego County, California. Just E-NE on hill on road to Aloha. L. G. Hertlein and U. S. Grant, IV, collectors. August 13, 1937.

"Pebbly arkosic sandstone. Microscopically, it consists largely of quartz, with abundant orthoclase, and acid plagioclase (some grains partly sericitized). Smaller amounts of biotite, magnetite, microcline and muscovite included in some of the quartz grains. The cement is silica. The grains are surrounded by a narrow rim of opal, and the interspaces are filled with fibrous chalcedony." (G. A. Macdonald).

No. 18. Pliocene. Loc. 417 (S.D.S.N.H.). Eight feet below fossiliferous conglomerate. Near International Boundary. L. G. Hertlein and U. S. Grant, IV, collectors. August 14, 1937.

LIGHT MINERALS:

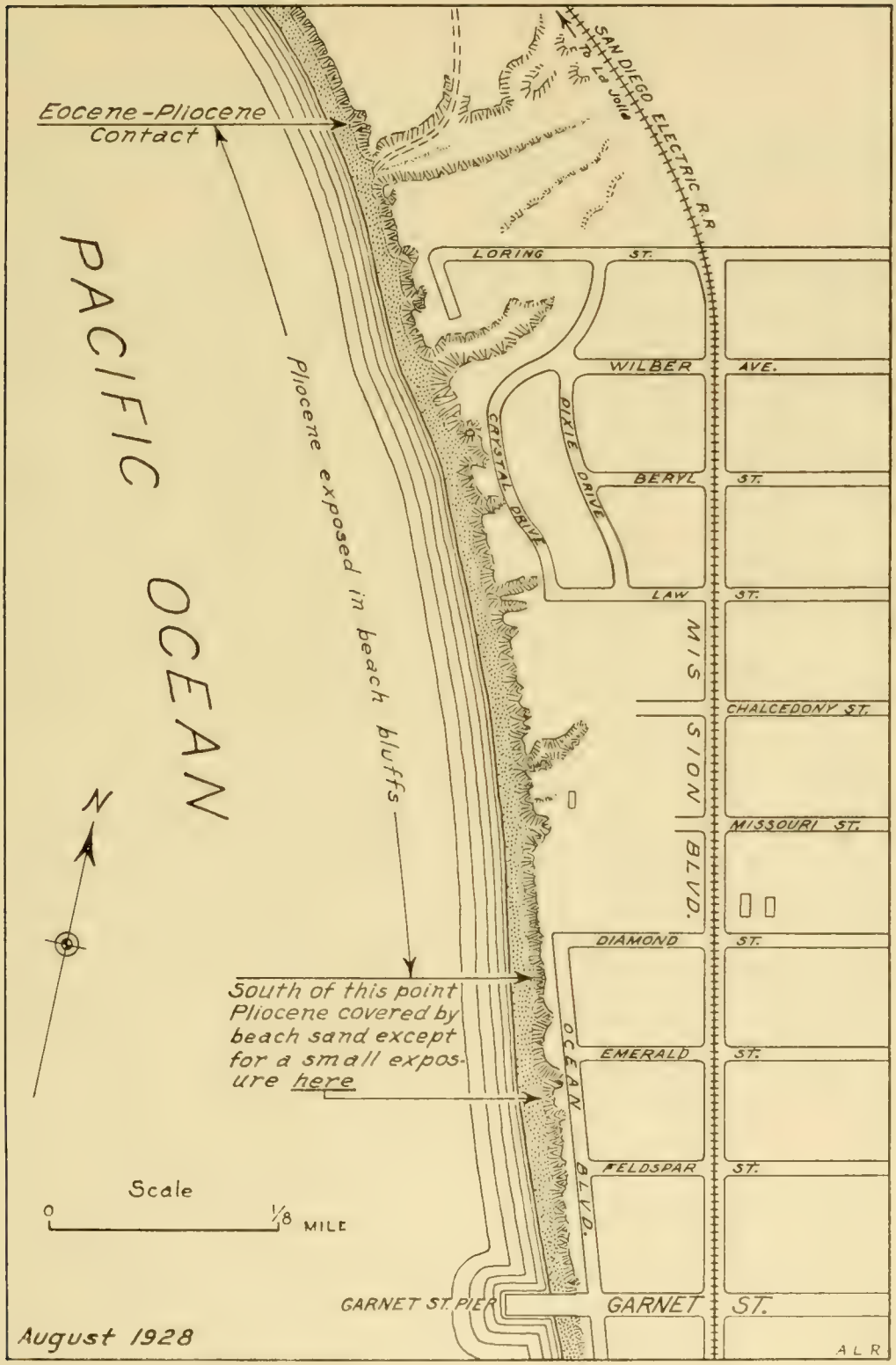
Quartz	52.3%
Orthoclase	19.8%
Oligoclase	9.9%
Acid andesine	4.9%
Albite	2.0%
HEAVY MINERALS:	11.1%

Magnetite—rare
Ilmenite—moderately abundant
Brown biotite—abundant
Green hornblende—abundant
Titanite—moderately abundant
Zircon—moderately abundant
Actinolite—moderately abundant
Epidote—rather rare
Zoisite—rather rare
Rutile—rather rare
Brown hornblende—rare
Colorless garnet—rare

"The grains range in size from that of silt up to about .07 mm. in diameter, most of them lying between .005 and .07 mm. They average about .04 mm. This sorting is moderately good. The grains are largely angular, with some subangular. The orthoclase is partially kaolinized.

"Epidote and zoisite are present in the Pliocene samples, and may have been derived from the older Eocene sediments. However, the presence of abundant hornblende and actinolite, and less abundant glaucophane, biotite, and other minerals not present in the Eocene sand examined indicate an additional source for much of the Pliocene sediment. Glaucophane, of course, indicates a Franciscan derivation; but whether the mineral was derived directly from its Franciscan source, or from older sandstone, is impossible to state." (G. A. Macdonald)

A number of years ago brick was manufactured on a small scale in the canyon now traversed by Reynard Way. This location is definitely in the Pliocene sediments which are fossiliferous nearby.



TEXT FIG. 5. Sketch map of a part of Pacific Beach showing the location of the Pliocene exposures in the beach bluffs.

The National Brick Company of National City operates on about 13 acres in a Pliocene area. However, most of the brick and tile plants utilize Eocene sediments, as related under our discussion of the Eocene.

PACIFIC BEACH AND SOLEDAD MOUNTAIN

Probably the best known section of the San Diego formation is that exposed at Pacific Beach. There the yellowish and bluish-gray Pliocene sands rest upon an erosion surface of the fine shaly gray and grayish-brown Eocene sandstones. The Eocene beds appear to strike N. 40° E. and dip about 12° SW. The Pliocene beds strike N. 50° E. and dip 11° SW. There appears to be almost no difference in dip between the two formations. The contact between the Pliocene and Eocene occurs in the beach bluff several feet north of the mouth of a small arroyo which has been cut through the Pacific Beach Terrace (Plate 8, figure 2, and Plate 9, figure 2). This contact dips below the beach about 1,740 feet north of the west end of Law Street. The exposed thickness of the Pliocene section at Pacific Beach is about 380 feet.

The underlying Eocene is a gray to yellowish-brown, very fine-grained shaly sandstone, well bedded and stained by limonite along the bedding planes. These beds contain concretions, some of which contain distinctive Eocene fossils. Deeper in the Eocene the strata are somewhat faulted and crumpled. The crumpling probably occurred in less competent members before consolidation took place. No typical clay shale was observed in any of the strata. Lower in the Eocene section thick layers of conglomerate appear. These outcrop in the higher cliffs at the northern end of Pacific Beach near Bird Rock.

The Pliocene and Eocene beds at Pacific Beach can be distinguished on both lithologic and palaeontologic evidence. The Eocene beds are harder, finer-grained, more grayish-brown in color, contain hard concretions and are less fossiliferous than the Pliocene. The very base of the San Diego formation is a conglomerate about 3 or 4 feet thick, which consists of large well-rounded cobbles (Plate 9, figure 2). This basal conglomerate rests upon an erosion surface of the Eocene, but due to lack of clear bedding planes in the Pliocene and slight irregularities in the Eocene, the difference in dip is difficult to detect with certainty, even instrumentally.

Overlying the conglomerate is a thick bed of rather massive yellowish and bluish-gray sandstone which contains numerous valves of *Pecten healeyi* Arnold; these occur abundantly thirty or forty feet above the base of the section. Above this loosely consolidated sand, are alternate layers of fossiliferous grayish and yellowish sands and harder cemented layers containing molds and casts of fossils. Arnold has already pointed out that *Pecten stearnsii* Dall and *Pecten bellus* Conrad are more numerous in the upper beds in the section at Pacific Beach. Cementation has progressed in a very irregular manner throughout much of the section exposed in the cliffs along the beach. This has resulted in hard, ragged, projecting layers separated by loose sand (Plate 8, figure 2, Plate 10, figure 1; also Plate 11). Some layers, however, have been uniformly cemented and their superior hardness has caused them to weather out as shelves dipping south-east about 8°. One such layer appears near the top of the bluff south of the west end of Law Street (projected) and continues visible for about 750 feet toward the south before it dips below the sands of the beach. This particular bed contains numerous molds of a *Glycymeris* and other mollusks.

About 1,200 feet south of the west end of Law Street the Pliocene dips below the beach sand but the southern portion of the Pliocene is largely obscured by talus from the overlying Pleistocene. Just south of Diamond Street the Pliocene strata apparently flatten out, for, although they are hidden beneath beach sand, the cobble layer at the base of the Pleistocene continues and is visible just above the beach at the foot of the bank south for some distance. Between Emerald and Feldspar Avenues, at the foot of the embankment and beneath the Pleistocene conglomerate, a small ledge of Pliocene is exposed. This might be due to a slight local upwarp in the strata or an irregularity in the surface upon which the Pleistocene was deposited. No Pliocene is exposed south of Feldspar Avenue and the embankment back of the beach gradually becomes lower until it disappears beneath the sand a short distance south of Garnet Avenue pier.

The Pliocene strata at Pacific Beach contain a number of characteristic Pliocene fossils. Among these are *Pecten healeyi* Arnold, *Pecten bellus* Conrad, *Pecten stearnsii* Dall, *Pecten* (*Swiftopecten*)

parmeleei Dall (rare), *Pecten* (*Lyropecten*) *cerrosensis* Gabb, *Pecten subdolus* Hertlein, *Arca* (*Anadara*) *trilineata* Conrad, *Opalia anomala* Stearns, *Opalia varicostata* Stearns, and *Lovenia hemphilli* Israelsky.

Soft yellowish-brown sandstones of Pliocene age are exposed on the south sloping spurs of Mount Soledad, where they overlie the Eocene sediments. These beds are generally weathered or covered with soil and brush, but they are well exposed in the sides of a small canyon about ⅜ of a mile west of the mouth of Rose Canyon. The beds here are generally quite soft and contain well preserved specimens of *Pecten healeyi*, *Pecten stearnsii* and *Pecten* (*Swiftopecten*) *parmeleei*.

SAN DIEGO MESA

South of Pacific Beach and Mount Soledad, no Pliocene rocks are exposed until the south bank of the San Diego River Valley is reached. Here the Pliocene strata overlie the Eocene, beginning at a point about one and a half miles up the valley from the Old Town Highway bridge. As the embankment becomes higher toward the east, the Pliocene section thickens until the upper fifty feet or more are Pliocene. The beds here are a light gray fine-grained sand with some nearly white beds. In the canyon at the north end of Sixth Avenue and just east of Mercy Hospital, a thin stratum which is hardened by cementation contains casts of mollusks, including the rather rare *Trophosycon*. The Pliocene-Eocene contact is a short distance below this indurated fossiliferous layer, but the lithology of both formations is so similar that it is difficult to detect the line of contact.

One of the striking features of the sedimentary rocks in the San Diego region is the similarity between the Pliocene and the Eocene. It is possible that the Pliocene beds are reworked Eocene sediment or came from the same or a similar source. This similarity, combined with the nearly horizontal attitude of both formations over a large area, and the obscure unconformity between them, as well as the scarcity of fossils at critical points, sometimes make the accurate determination of the contact a matter of difficulty. In general, the hard concretions and the better bedding of the Eocene sandstones distinguish them from the softer and less distinctly bedded Pliocene beds. Furthermore, no shale of any consequence is found interbedded with the Pliocene sediments, as is the case in the Eocene beds in that area. The small, hard, concretionary pebbles found on parts of the Eocene mesas are not present on the Pliocene mesas.

With the exception of small areas in the northwest and northeast corners, the entire San Diego mesa-lands, from the upper part of the south bank of the San Diego River Valley to the Mexican boundary, are formed of Pliocene sediments of the San Diego formation.

In a road cut about two-tenths of a mile southwest of Alamo Drive and Center Street in East San Diego, *Dendraster* sp. and *Acanthina spirata* were found at Loc. 1405 (C.A.S.). This indicates a Pliocene age, while about one-fifth mile northeast a massive whitish-gray conglomerate outcrops, which is apparently Poway, Eocene. Thus the Pliocene contact is in the immediate vicinity of that locality.

Terrace material caps much of the mesas, and Pleistocene deposits occur on some of the terraces, but these do not comprise an important element in the thickness of the mesas. The Pleistocene sediments form, in general, a fringe along the western foot of the mesas.

Yellowish-brown and gray, fine to medium-grained sandstones are by far the most important sediments, in point of volume, of the Pliocene formation; but thin beds of gravel and lenses of conglomerate are locally exposed. Some of the sands are noticeably micaceous, but this is not common.

Clay and shale are of rare occurrence in the San Diego Pliocene. No very large body of either material was detected in any of the exposures visited during the field work. A peculiar colloidal clay (bentonite), with a soft soapy feel when wet, occurs in a thin layer a little more than half way up the mesa on the north and south sides of Otay Valley, a little over a mile west of the Otay Land Grant boundary line. This, according to Eakle,[172] is montmorillonite and is locally known as "Otay-

[172] Eakle, A. S., Calif. State Mining Bureau, Bull. 91, p. 223, 1923; also Pabst, A., "Minerals of California," State of Calif., Dept. Nat. Resources, Division of Mines, Bull. 113, p. 238, Feb., 1938. For additional data see Schroter, G. Austin, and Campbell, Ian, "Geological Features of Some Deposits of Bleaching Clay," Amer. Inst. Min. Metall. Eng., Tech. Publ. 1139-H. 82, I. 89, p. 6, figs. 7, 8, Jan., 1940.

lite." This clay layer is but three to seven feet thick and lies interbedded with gray fine-grained Pliocene sands. At two localities on the south side of the valley it was formerly mined for use in purifying petroleum. More recently a smaller quarry on S. H. Perlmutter's ranch on the north side of Otay Valley, almost due north of the older quarries, has been intermittently worked by Standard Oil interests. This stratum may be more widespread than present development would indicate, but it is difficult to detect unless favorably exposed and it was not helpful as a definite horizon marker during our field work. Where exposed in the sides of Otay Valley it can be seen forming a white line around the mesa. At some places the beds may have a slight eastward dip. These occurrences, together with the nine-inch bed of bentonite exposed on Federal Avenue just east of 35th Street in San Diego, and the bentonitic bed penetrated by a shaft at the east end of the Natural History Museum Building in Balboa Park, are the only clay material observed by us in the San Diego formation.

The well, Otay Mesa No. 1, drilled by the Itasco Petroleum Company in Section 33, Township 18 South, Range 2 West, San Bernardino Base and Meridian, showed, at a depth of 1,150 feet, a core described as of soft gray sand, silt and shale, which is probably Pliocene in age. At a depth of 1,560 feet, a gray hard amorphous rock without bedded structure, apparently metamorphic, was reported. The San Diego Oil and Gas Company's Tia Juana River Well appears to have drilled through the base of the Pliocene at a depth of 1,680 feet and penetrated Sespe or Poway Eocene to 3,040 feet, where Eocene shale was encountered. At 3,400 feet the lithology suggests that Cretaceous may have been encountered but these age determinations have not been checked by us.

Ellis[173] has furnished a series of logs of wells located in the San Diegan coastal region, some of which indicate a great thickness of sedimentary rocks.[174] The data from these logs are mostly lithologic in nature and there is no paleontologic evidence to permit a recognition of the Pliocene-Eocene contact. The log of the Lo Tengo Oil Company's well, which was located on the Otay Mesa a little less than two miles north of the Mexican Boundary at Tia Juana, showed a thickness of sedimentary beds of about 3,400 feet. Part of this may have been Eocene, possibly even Cretaceous in age. Ellis reproduced logs of two other wells in the southern part of the Pliocene basin, one with a depth of 1,405 feet, the other 1,812 feet, both of which were in sedimentary beds at the maximum depths. It is unfortunate that these logs contain no fossil evidence by which the depth of the Pliocene sediments can be determined. From the general structural relations of the Pliocene series in this basin as a whole the writers are of the opinion that the San Diego formation in the vicinity of Otay Mesa attains a thickness of about 1,275 feet.

Through the generous cooperation of Mr. J. E. Pettijohn we have been permitted to include here portions of the geologic report of Mr. George H. Doane on the San Diego Gas and Petroleum Corporation's Holderness No. 1 Well, located in the southeast quarter of Section 32, Township 18 south, Range 2 west (San Bernardino Base and Meridian), about 16 miles south of the City of San Diego

[173] Ellis, A. J., in Ellis, A. J., and Lee, C. H., U. S. Geol. Surv., Water Supply Paper 446, pp. 66-67, 1919.

[174] Over fifty dry holes have been drilled in San Diego County in search of oil. We have looked over the logs of many of these where they were available, but as most of the subsurface data consists of drillers' descriptions of lithology without any significant paleontologic facts little of value was obtained. The following are of some interest in presenting evidence in regard to the depth of sedimentary rocks:

Community Oil Well Co., Scott Well No. 5. Lot 1194, T. 16 S., R. 3 W., S. B. B. and M., 1919. At 1,274 feet depth shale and sandstone were logged.

Choate and Overbaugh, Encanto Well.. Tract 11, San Diego, 1925. Driller's log from surface to 1,235 feet, where it was reported to end in sandstone and limestone.

Paradise Oil Co., Well No. 1, Rancho de la Nacion. Elevation 290 feet, April 1, 1927. Penetrated 2,130 feet of sediments, and at that depth hard limestone and sandstone were logged.

Borderland Exploration Co., Point Loma Well No. 1. Pueblo Lot 211. Abandoned 1932. Drilled to 5,101 feet where brownish gray shale and sandstone were logged.

Borderland Exploration Co., Point Loma Well No. 2. Pueblo Lot 258. Three hundred feet northerly, 175 feet easterly from the southwesterly corner on the northeasterly quarter of Pueblo Lot 258. Started Nov. 13, 1931, abandoned March, 1933. Drilled to 2,610 feet, "gray shale" at bottom.

National City Oil Co., Well No. 1. Sect. 22, T. 18 S., R. 2 W., S. B. B. and M., 1933. Driller's log from surface to 2,625 feet. Last hundred feet reported as "Red rock, cave. Shale-brown. Sand-fine. Lime, showing oil."

The Petroleum World, Annual Review, 1936, p. 162, gives a brief list of dry holes in San Diego County with their total depth but no logs.

See also, Hertlein, L. G., and Grant, IV, U. S., Calif. Journ. Mines and Geol., Vol. 35, no. 1, 35th Rept. Calif. State Mineralogist, pp. 74-77, Jan., 1939, [received at library of the California Academy of Sciences Aug. 23, 1939].

and one and one-half miles north of the International Boundary, elevation 20 feet. This is near the mouth of the Tia Juana River. Mr. Doane began his examination when the well was drilling below 3,900 feet, but he also examined the higher cores and samples. From his examination of these cores and samples he compiled the following geologic column:

	Depth in feet	*Thickness in feet*
Alluvium	0- 300 ?	300
San Diego Formation	300-2,900 ?	2,600
La Jolla Formation		
Rose Canyon Shale	2,900-3,800	900
Delmar	3,800-3,900	100
"Chico" Formation	3,900-5,260	1,360
Trabuco Formation	5,260-5,529	269
Black Mountain Formation	5,529-6,332	803 plus

"Geophysical survey proves beds rising in southwesterly direction from Holderness No. 1 Well, the dip being 12-15 degrees which is the same as that seen in the cores of the well and definitely showing a structurally high area to lie southwest of the well. No definite proof of closure is seen in the evidence." (From report by G. H. Doane, April 27, 1936).

According to a subsequent geophysical survey made by International Geophysical Company in connection with underground water problems in the Tia Juana River Valley, the bottom of the valley alluvium at the Holderness Well should be at about 115 feet below mean sea level. If this determination is correct, then the San Diego formation at this locality is a little thicker than the estimate given in the table above or there are some post-San Diego beds present beneath the valley alluvium.

According to Mr. Doane's report non-marine reddish colored beds were encountered below a depth of 2,485 feet which he suggests might represent a thin "finger" of the "Sespe" formation. If the section between 2,485 and 2,900 feet belongs to the "Sespe" formation or the Poway formation then the San Diego formation may be only 2,185 feet thick or possibly much less. According to Mr. F. B. Tolman, the greatest depth at which Pliocene fossils were encountered was 1,680 feet. If this latter depth represents the base of the Pliocene sediments, then the San Diego formation would have a thickness in this well of about 1,380 feet.

The report by Mr. Doane mentions the occurrence of slickensides and minor fracturing in cores between depths of 5,018 and 5,042 feet, but we do not know whether or not this is significant of any important faulting.

Distinctive Pliocene fossils occur at a number of localities in the mesas and canyons in the environs of San Diego, southeast to the Chula Vista district and in the mesa along the Mexican Boundary. These localities and the fossils will be described in detail in the systematic part of this paper, which is planned for later publication. In some of the excavations along India Street, particularly at the corner of Upas Street, *Pecten healeyi* and *Pecten stearnsii* are common, with occasional specimens of *Ostrea erici, Sinum scopulosum, Glottidia albida* and others. In Balboa Park a large *Dosinia* is exceedingly abundant just south of the west end of Cabrillo Bridge, and *Merriamaster pacificus* Kew has been obtained in Cabrillo Canyon. Farther east and south numerous Pliocene species have been collected by the authors, Messrs. Frank Stephens, Frank B. Tolman, E. H. Quayle and others. *Pecten subdolus* Hertlein is common on Market Street one-tenth mile east of Euclid Avenue and *Ostrea vespertina* Conrad is exceedingly common near the intersection of Thirty-fourth and Tompkins Streets. Farther south the authors have obtained *Dendraster ashleyi* Arnold just west of Cockatoo Grove, *Pecten healeyi* and *Dendraster ashleyi ynezensis* Kew in the Chula Vista District; and near the Mexican Boundary about three-quarters of a mile from the sea, where the dip is about 9° to the west, Messrs. Tolman and Quayle and the authors have collected *Pecten bellus, P. healeyi, Pecten* (*Swiftopecten*) *parmeleei, Arca trilineata calcarea* and many other species.

Some geologists have suspected that a part or all of the mesa along the Mexican Boundary south of the Tia Juana River is composed of Eocene strata. That this is not correct is proved by the Pliocene fossils occurring just back of the beach (Locs. 294, 310 and 312, U.C.L.A.) and also the occurrence of numerous specimens of *Pecten* (*Patinopecten*) *healeyi* from the bottom (60 feet) of David Smallcomb's well just north of the Mexican Boundary, in the bottom of Matadero Canyon four-tenths of a mile west of the United States-Mexico Boundary Monument No. 256 (see U. S. Geol. Surv., Topo-

graphic Map of San Diego Quadrangle, Edition of June, 1904). The discovery by Mr. Quayle of the occurrence of this characteristic Pliocene pecten in Smallcomb's well definitely proves that all of the mesa north of the International Boundary in this vicinity is of Pliocene age. These beds extend a few miles south of the International Boundary, where they are overlain by Pliocene volcanic rocks. A brief reconnaissance in the coastal region south of Tijuana indicates that the Pliocene beds extend several miles south of the International Boundary where they rapidly become ashy. In the vicinity of Rosarito, about 27 kilometers (17 miles) by road south of Tijuana, vesicular basic lava flows alternating with ashy sands and silts form most of the terrain. Three miles south-southwest of Table Mountain, a prominent peak 2,402 feet high, appears to be a volcanic neck from which lava flows and tuffaceous deposits in that vicinity originated. These beds are inclined outward from this center, dipping gently for the most part but steeply inclined near the old vent. Although recognizable fossils were not found in these ashy deposits, their relationship to the marine Pliocene near the Boundary suggests that they may be of late San Diego age. In the environs of La Mision (old San Miguel Mission) about 64 kilometers (40 miles) by road south of Tijuana, a thick basic lava flow forms a conspicuous surface surrounding occasional monadnocks of plutonic rock. This lava may also be of Pliocene age.

In addition to the marine Pliocene invertebrates, Professor Loye Holmes Miller of the University of California at Los Angeles has reported two extinct Pliocene birds from the San Diego formation. These are *Mancalla californiensis* Lucas,[175] of which the fragment of a humerus was collected at the Euclid Avenue quarry, and *Pliolunda diegense* L. Miller,[176] described from a femur discovered in the marine beds on Market Street near Euclid Avenue. The *Mancalla,* an extinct Auk, was originally described from a humerus found well down in the Pliocene in the Third Street tunnel in metropolitan Los Angeles. The *Pliolunda diegense* represents an extinct genus of Puffin. Both of these birds of extinct genera seem to be unquestionably Pliocene in age.

The widespread though rather sporadic occurrence of Pliocene fossils is evidence of the extensive distribution of the San Diego formation in this region.

STRUCTURE

The structure of the San Diego formation is comparatively simple. None of the Cretaceous or Cenozoic sedimentary rocks in the San Diego basin have been greatly deformed since their deposition. Possibly the lack of the effects of orogenic diastrophism is partly a reflection of the relatively thin cover of incompetent sediments overlying the hard brittle crystalline rocks which make up the basement complex. The total known thickness of all the unmetamorphosed sedimentary rocks resting on the Black Mountain volcanics is less than six thousand feet in the San Diego region. In this respect the San Diego basin is very different from some of the other California Tertiary basins, such as the Ventura basin, where twenty to thirty thousand feet or more of sedimentary rocks accumulated before they were folded and overthrust during the mid-Pleistocene Pasadenan orogeny.

At the northern end of the Pliocene basin, at Pacific Beach and on the south slopes of Mount Soledad, the yellowish-brown Pliocene sands dip about 8° south-southeast. These Pliocene sands on the south slope of Soledad Mountain are obscured by Pleistocene sands and terrace material before reaching the shore of Mission Bay. This inclination represents a part of the gently dipping south limb of the Soledad Mountain anticline, which has an axis trending northwest-southeast and which passes just north of the summit of Soledad Mountain. The axis of this anticline plunges in both directions from near the summit of Mount Soledad. The north limb has much steeper dips than the south limb, particularly between the summit of the mountain and Rose Canyon, and general field relations suggest that the force which produced the fold was ultimately dissipated by movement along the Rose Canyon fault. This fault originated as a result of the same force which produced the fold. On the east side

[175] *Mancalla californiensis* Lucas, Proc. U. S. Nat. Mus., Vol. 24, p. 133, 1901. — L. Miller, Condor, Vol. 35, no. 1, pp. 34-35, Jan., 1933. — Woodring, U. S. Geol. Surv., Prof. Paper 190, pp. 6, 7, 1938.

[176] *Pliolunda diegense* L. Miller, Trans. San Diego Soc. Nat. Hist., Vol. 8, no. 29, pp. 375-378, text figs. 1, 2, Dec. 15, 1937

TEXT FIG. 6. Areal geologic map and cross-section of Soledad Mountain. The areal distribution of the Cretaceous, Eocene, Pliocene and Quaternary sedimentary rocks is shown on this map without attempt to include all the terrace deposits. The Pleistocene and Recent deposits have been combined under Quaternary and indicated where the areal extent is sufficient to be clearly shown on this small-scale map. Horizontal distance of cross-section about four miles. Vertical and horizontal scales are the same.

of Rose Canyon, just above the first bend in the canyon, some of the beds of Rose Canyon shale dip about 20° northeastward, reflecting the presence of the north limb of the subdued anticline east of the Rose Canyon fault. The movement on the Rose Canyon fault was partly horizontal, the west side moving northward, but the west side in the Mission Bay area also dropped down with respect to the beds on the east. In Rose Canyon this fault can be detected by the difference in attitude of the beds on opposite sides of the canyon. Farther south, along the east shore of Mission Bay, a continuation of the fault is suggested by the former presence of a small spring near Morena and the steep (45°) southward dip of a small tilted block which once formed a little knoll (now removed by grading) just north of Old Town. The fault movement apparently accompanied the later stages of the folding or was subsequent to it. Although the folding of the Eocene beds in Soledad Mountain may have begun at a time preceding the last wave-truncation of the Kearny or Linda Vista Mesa, it must have continued after the regression of the sea because the Pliocene beds on the southern lower slopes of Soledad Mountain are dipping southward at an angle probably greater than their original inclination during

deposition, and the terraces on Soledad Mountain are higher than those which may be their correlatives in the mesa-lands to the east.

No Pliocene beds were detected on the north end of Point Loma which lies south of Mission Bay (False Bay), and since the older beds on Point Loma have a prevailing eastward dip there is no conclusive surface structural evidence of a syncline in the Mission Bay region. At least the south limb of such a syncline, if present, is not visible and the absence of Pliocene beds on the north end of Point Loma can be readily explained by an east-west fault with the down throw on the north side. This fault, if it exists, probably extends from the neighborhood of the present entrance to Mission Bay eastward across the delta flats and an unknown distance up Mission Valley. If present, it is entirely concealed beneath the Quaternary alluvium of the delta flats and valley bottom. Point Loma possibly may be the remnant of an eastward tilted block bounded by faults on both east and west sides with general north-south trends. The position of such faults would be beneath the bay and ocean, and, in the northeast, beneath the Quaternary alluvium.

The Pliocene strata of the San Diego Mesa dip gently toward the south and southwest, amounting to about 4° to 6° in Cabrillo Canyon, Balboa Park. At many outcrops the sands are not sufficiently well bedded to permit careful measurements, but it is safe to say that the average of all outcrops indicates a gentle inclination to the south or southwest. In general, the angle of dip decreases from north to south in this embayment, and there is some evidence to suggest a decrease in angle of dip as the eastern margin of the basin is approached. From Las Choyas south to the Mexican Boundary the dip is generally less than it is in the northern areas, which indicates some flattening out of the beds at certain places in the southern part of the basin. In this southern part, slight dips toward the east and west were occasionally detected, but the inclinations were so low that little importance is attached to them from a structural standpoint, except as indications of local irregularities or unevenness in the beds. Steep dips in the beds at places along the south margin of Otay Mesa, such as occur near San Ysidro, appear to be due to land-slides and not to orogeny.

Cross-bedding occurs locally in medium fine-grained gray sands and occasional lenses of pebbles and cobbles. This is rare in the fine-grained yellowish-brown sands, and throughout the formation it is not a common feature.

The Pliocene beds near the Mexican Boundary and about three-quarters of a mile east of the beach have a dip of about 9° toward the west. The considerable thickness of conglomerates to the east suggests that this dip may be due at least in part to the dip of foreset beds of the delta of the ancient Tia Juana River. Likewise the conglomerates in the Pliocene west and southwest of La Mesa may be part of the delta of the precursor of the San Diego River.

No faults of major importance were detected in the San Diego Pliocene Mesas. A small fault with perhaps 15 feet displacement occurs in one of the clay pits on the south side of Otay Valley, about a mile and a quarter west of the Otay Land Grant boundary line. Other such faults exist, but they are small and of a local nature. There is some slight physiographic evidence of a fault obliquely crossing the International Boundary in the mesa between Boundary Monuments Nos. 256 and 257, but we were unable to detect corroborative geologic evidence of its existence in our brief field work west of Tijuana. In the eastern margin of the basin the Pliocene sands rest on the eroded surface of the older crystalline rocks with no indication of faulting. Between the Pliocene and Pleistocene there is likewise no indication of faulting.

AGE AND CORRELATION

In the concluding part of this memoir the authors propose to present an analysis of the fauna of the San Diego formation and a discussion of its age and correlation with some other important Pliocene localities. As the present part of this work does not include a treatment of the fauna of the San Diego formation it would be premature to attempt a thorough discussion of age relations at this time. From what has been accomplished so far, the authors are convinced that the San Diego formation is of Pliocene age and that it is probably equivalent, in part, to the Pliocene of Cedros Island, Lower California, Mexico, the Pliocene of Elsmere Canyon near Newhall, Los Angeles

County, the Pliocene near the mouth of Temescal Canyon, north of Santa Monica, and the Pliocene north of Simi Valley in Ventura County. Although the upper and lower limits of the Pliocene series in California may be subject to revision, the San Diego formation may be tentatively considered middle Pliocene.

THE SWEITZER FORMATION

Most of the mesas in the San Diego region are overlain and capped by a formation of brownish-red resistant sandstone and conglomerate, which, due to its superior hardness, often weathers out as a prominent layer at the top of the mesas. The widespread distribution of this hard brownish-red layer is a striking feature of the geology of the region. For this formation the name Sweitzer formation[177] was proposed by the senior author.

This formation is generally readily distinguished from the finer-grained, softer, better sorted, yellowish to bluish-gray sands of the San Diego formation, and a close inspection of favorable exposures reveals an unconformity between the two. Such exposures occur near the heads of some of the lateral canyons leading off Sweitzer Canyon and Cabrillo Canyon in Balboa Park, San Diego. As the lithology is characteristically represented in natural outcrops and road cuts in and adjacent to Sweitzer Canyon,[178] this area has been designated as the type locality for the formation.

The Sweitzer formation is constant in its position overlying the Pliocene sands of the San Diego formation and is therefore clearly later in age. It also caps the Eocene on some of the mesas north of the San Diego River. At a number of places it not only caps the higher mesas but extends down over their margins onto the next lower terrace and apparently in some instances continues even lower. In parts of Balboa Park in the City of San Diego the marine Pliocene beds have a dip of 6° to 8° south-southwest and since the Sweitzer overlies them in a nearly horizontal attitude, the relationship between these two formations is that of an angular unconformity[179] (Plates 12, 13 and 16). Due to lack of clear bedding planes this irregularity cannot always be readily observed, but where the contact is well exposed in a fresh cut a definite line can be detected between the brownish-red sands and gravels of the Sweitzer above and the yellowish to bluish-gray sands of the San Diego formation below. In old cuts and weathered natural exposures the contact is often obscured by a ferruginous mud which washes down from the Sweitzer and soil above onto the San Diego beds below. While the lithology of these two formations is characteristically very different, sometimes the lower, less conglomeratic part of the Sweitzer is well bedded and resembles the alternating sand and gravel layers of the San Diego formation. In such cases a close inspection generally permits recognition of the Sweitzer by its less well sorted and generally coarser sand, not to mention again the color differences.

The Sweitzer formation varies from a thin stratum to beds over 20 feet thick. The conglomerate occurs as layers, lenses, or pockets in the sand, but is more commonly concentrated in the uppermost part. The proportion of gravel and cobbles to sand varies greatly. The cobbles of the conglomerate are generally well rounded and vary in size from a few centimeters in diameter up to boulders three feet or more in maximum diameter. Their average size is perhaps less than one foot. They represent a variety of rocks, including agglomerates, porphyry, and dense fine-grained igneous rocks. They are all very hard, generally not strongly foliated, and cobbles of quartz diorite are exceedingly rare.

As already mentioned, the reddish-brown conglomeratic sandstone of the Sweitzer formation occurs in some instances below the tops of the mesas, but except for the conglomeratic sands occurring on the Sub-Otay Terrace and parts of the Avondale Terrace, the material on the lower terraces may not belong to the Sweitzer formation. Apparently the lower level conglomerates and gravels are later Pleistocene Terrace deposits, although they may have been derived in part from reworking of the Sweitzer. In some localities what appear to be beach deposits on the mesas are associated with the

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[177] Hertlein, L. G., Stanford Univ. Bull., 5th Ser., Vol. 4, no. 78, p. 82, 1929.

[178] Sweitzer Canyon is the large canyon east of Cabrillo Canyon in the northeast corner of Balboa Park. An excellent exposure of the Sweitzer formation is present in a branch of Sweitzer Canyon locally known as Powder House Canyon.

[179] This was noticed a number of years ago by Professor George D. Louderback (Trans. San Diego Soc. Nat. Hist., Vol. 2, no. 3, p. 88, 1916).

Sweitzer formation. These deposits, which are younger in age, occasionally form definite beach ridges. They are discussed briefly in the account of the physiography.

The gravels and sands of the Sweitzer formation are not continuous throughout the mesa regions. On some of the eastern parts of the Otay Mesa the Sweitzer is apparently absent, but in all these cases the elevations are below the general mesa level. This suggests that erosion has removed some of the top of the terrace there. Moreover, those areas from which the Sweitzer is absent are, at least in some cases, areas which were subjected to erosion by streams of an earlier interrupted cycle of erosion described earlier in this paper.

The Sweitzer formation resembles somewhat the Eocene Poway conglomerate but the Sweitzer is much thinner, the boulders and cobbles are not so well sorted, and the color is generally a brownish-red, although in some localities the formation is a light gray. Furthermore, the resistant nature of the Sweitzer appears to be due in many observed instances to a ferruginous mud cement. The Poway conglomerate is better sorted and occurs in more massive, thicker beds. The latter, of course, is of Eocene age and more comparable to the Sespe formation which is so well known to the north.

The soils developed from the Sweitzer formation are characterized by what soil experts refer to as maturely weathered profiles with a clay or hardpan subsoil beneath the surface. Soils of the Redding series and the Olivenhain series[180] are characteristically developed on the Sweitzer formation. Prairie mounds frequently occur on these soils.

Origin of the Sweitzer Formation

From the standpoint of lithology it can be inferred that the Sweitzer formation represents a decided difference in conditions of sedimentation from those which prevailed during the deposition of the underlying finer-grained sediments. The coarser sandstone and the characteristic conglomerate of the Sweitzer formation must have required strong currents to distribute the sediments over such an area. This rather wide distribution could scarcely have been accomplished entirely or even largely by rivers, since the strong currents required would presuppose a steep gradient which, in turn, would have resulted in deeply entrenching the soft underlying sandstones. Although some entrenching of the underlying San Diego beds has occurred in certain localities, such as northeast of Balboa Park, it took place on a small scale and is not common. While any interpretation[181] of past conditions based on incomplete data must of necessity be an assumption, one might be inclined to accept the simplest theory which will explain all the observed facts. In the present case, therefore, one may assume that the Sweitzer formation represents distribution by ocean waves and near shore currents of coarse material derived by wave erosion on the Poway conglomerate or by stream erosion on older rocks in the mountainous region to the east. After the deposition of the uppermost San Diego beds, the region was elevated sufficiently for wave erosion or sea floor scour to truncate the marine Pliocene and Eocene beds. It is possible that this elevation was of a differential nature and that the mountainous region far east of the area under immediate consideration was uplifted to a much greater extent than that along the coast. At any rate the uplift may have been sufficient to greatly rejuvenate the streams and enable them to transport coarser material such as medium to coarse-grained sand, gravel, and boulders. This material would in that case have been deposited in relatively shallow water at the mouths of the streams and from there distributed by the waves over a large area of the shallow bottom. Such an uplift, rejuvenating the streams, would elevate the San Diego and the Eocene beds so that their upper surface would be at or near sea level. It is probable that the northern part of the San Diego Mesas[182] may have been elevated more than the southern part, since the strata in the northern part, as in Balboa Park, have

[180] See Storie, R. E., and Carpenter, E. J., "Soil Survey of the El Cajon Area, California," U. S. Dept. Agric. Ser. 1930, no. 15, 42 pp., map, 1 text fig.

[181] For an excellent paper on this subject see "Marine and Terrestrial Conglomerates," by J. Barrell, Bull. Geol. Soc. Amer., Vol. 36, no. 2, pp. 279-341, 6 text figs., 1925. (Ed. by C. Schuchert).

[182] The term San Diego Mesas refers to all the mesa lands from the San Diego River Valley south to the Mexican Boundary. The mesa north of San Diego River Valley is generally referred to as the Linda Vista Mesa or Camp Kearny Mesa.

been more distinctly truncated. The present upper surface of the San Diego formation, then, probably represents a plain of marine denudation although it may not have been exposed as dry land until after deposition of the Sweitzer formation.

It is possible that parts of the San Diego formation were elevated slightly above sea level at the close of the diastrophic movements which inaugurated Sweitzer time. If such did occur, the soft nature of the San Diego beds resulted in their quick destruction by the waves and their reduction to a shallow submarine platform. It is on this platform, possibly partly produced by wave reduction of loose sandy cliffs and partly by wave scour on a very shallow soft bottom, that the Sweitzer formation was deposited. Unfortunately no fossils were found in the Sweitzer formation. Considering the rarity of fossils in general, their absence in this case is inconclusive. The water may have been decidedly brackish near the mouths of the rivers, but it appears to the authors that the formation is at least partly marine in origin. Its age can only be positively stated as later than San Diego and earlier than the uplifts which are now represented by the Pleistocene terraces fringing the margins of the mesas.

At our request Dr. Gordon A. Macdonald kindly made a sedimentary analysis of a typical specimen of the finer-grained part of the Sweitzer formation of Balboa Park. His report follows.

No. 19. Balboa Park, San Diego, California. Sweitzer formation on east side of street railway cut, 75 yards south of trestle, about 200 yards south of north boundary of Balboa Park, 100 yards east of Park Boulevard. U. S. Grant, IV, collector. Dec. 5, 1937.

LIGHT MINERALS:

Quartz	50.2%
Orthoclase	35.2%
Plagioclase (oligoclase to andesine)	10.1%
Microcline	1.0%
Rock fragments	3.0%

HEAVY MINERALS: 0.5%

Magnetite—abundant
Ilmenite—abundant
Green hornblende—abundant
Actinolite—abundant
Brown biotite—abundant
Augite—moderately abundant
Epidote—abundant
Zoisite—rather rare
Glaucophane—moderately abundant
Zircon—moderately abundant
Pale pink garnet—rather rare
Titanite—rare
Brown tourmaline—rare

"Sorting is moderately good. The grains range in size from about .05 mm. to about .3 mm., and the average size is close to 0.15 mm. The sample contains one sub-rounded pebble 2.5 cm. across. The grains are largely angular in outline, but a few are subangular. They are weakly cemented together with brownish-yellow clay material. In general, the grains appear quite fresh, although some of the orthoclase has been slightly kaolinized, and the biotite is universally bleached to a pale golden-brown color.

"Lithologically, the Sweitzer sand is quite similar to the sands of the San Diego Pliocene which I examined for you last semester. The heavy minerals include many of the same types. Like the San Diego Pliocene sands, the original source of many of the minerals, such as glaucophane, was a metamorphic terrane of Franciscan type. Other minerals, such as the biotite, and zircon, may have been derived from granitic source rocks. All, of course, may have gone through an intervening sedimentary cycle, and in their present locus may have been derived from older sedimentary rocks — possibly the Pliocene sands. The angularity and freshness of many of the grains, especially of the feldspar, however, makes it seem improbable that they have suffered any very great degree of re-handling. There is no evidence of wind action on the surfaces of the grains, and the degree of sorting suggests water transportation. The angularity of the grains would appear to indicate that this transportation was not over very great distances. The freshness of the minerals, particularly the feldspar, indicates that the rate of erosion was rapid in comparison to the rate of weathering in the source area. All together, the Sweitzer sand is quite similar to those of the Pliocene, and quite different from the sample of Eocene sand which I examined." (G. A. Macdonald).

At a later date Dr. Macdonald made some supplementary remarks about the sample of Sweitzer sediment he examined.

"Regarding the Sweitzer sand — I seem to have neglected to mention the color differences between the Sweitzer and the Pliocene sands. As you say, they appear quite different. The Sweitzer is pale reddish-brown in color, while the Pliocene sands are gray. Also, the one sample of the Sweitzer is less well sorted than the majority of the Pliocene samples. The color indicates deposition under oxidizing conditions, and both this and the fact that it is only moderately well sorted suggest that it is of non-marine origin, while the Pliocene is marine." (G. A. Macdonald).

PLEISTOCENE

The marine fossiliferous Pleistocene deposits of the San Diego region have been mentioned, briefly discussed, or their fauna partially published by a number of authors, beginning with Dall[183] in 1878. From the "San Diego Peninsula," now known as the Coronado peninsula, Dall listed over 40 species which are of Pleistocene age, including in the lowest part of the beds the recent warm water species *Dosinia ponderosa* Gray. In the same paper Dall also listed some upper Pleistocene fossils from the mainland in the City of San Diego and from the upper beds at Pacific Beach. Later he definitely referred these to the Pleistocene and correlated the horizon with the "San Pedro beds" in Los Angeles County.[184]

In his monograph on "The Paleontology and Stratigraphy of the Marine Pliocene and Pleistocene of San Pedro, California,"[185] Ralph Arnold described the Pliocene and Pleistocene of various other localities in California, including those in the vicinity of San Diego. In describing the fossiliferous Pleistocene sands and gravels overlying the San Diego formation at Pacific Beach, Arnold pointed out their similarity to the "Upper San Pedro deposits," now known as the Palos Verdes formation,[186] but remarked[187] that "the break between the faunas of the Pacific Beach Pliocene and the overlying Pleistocene is much greater than that between the Deadman Island [Timms Point formation][188] and its overlying Pleistocene (lower San Pedro series) layer." This observation on the relative magnitude of the faunal breaks in the two regions is amply borne out by all later paleontologic work. The *Arca* (*Anadara*) *trilineata, Pecten healeyi, Pecten* (*Swiftopecten*) *parmeleei,* and other species in the Pacific Beach Pliocene, so far as now known do not range sufficiently high in the Pliocene to occur in the Deadman Island Pliocene [=Timms Point formation]. Furthermore, the Pacific Beach Pleistocene is probably much younger than the lower San Pedro series of the Los Angeles basin.

Arnold listed 59 species from the Pacific Beach Pleistocene to which Stephens[189] has added eight. This fauna lacks some of the species so abundant at or diagnostic of other late Pleistocene localities in the environs of San Diego, such as *Chione gnidia, Amiantis callosa, Dosinia ponderosa* and others.

183 Dall, W. H., "Distribution of California Tertiary Fossils," Proc. U. S. Nat. Mus., Vol. 1, pp. 26-30, 1878. In this paper, lists of both Pliocene and some Pleistocene fossils were included. Many years earlier Wm. P. Blake had called attention to a "thick layer of large and small shells near the top of one of the banks bordering the beach, and about twenty feet above the water," at some undefined locality in the environs of San Diego, but he mentioned no species by name. (U. S. Pacific R. R. Repts., Vol 5, pt. 2, pp. 128-129, 1857).

184 Dall, W. H., U. S. Geol. Surv., 18th Ann. Rept., Part 2, p. 335, 1898.

185 Arnold, R., Mem. Calif. Acad. Sci., Vol. 3, 420 pp., 37 pls., 1903. Reprinted as "Contributions to Biology from the Hopkins Seaside Laboratory of the Leland Stanford Jr. University, No. 31," 1903. See especially pp. 57-64.

186 Tieje, A. J., Bull. Amer. Assoc. Petrol. Geol., Vol. 10, no. 5, pp. 502-512, 1926. — Woodring, W. P., "Fossils from the marine Pleistocene Terraces of the San Pedro Hills, California," Amer. Journ. Sci., Ser. 5, Vol. 29, no. 171, pp. 292-305, 1 fig., March, 1935. — Willett, G., "An upper Pleistocene Fauna from the Baldwin Hills, Los Angeles County, California," Trans. San Diego Soc. Nat. Hist., Vol. 8, no. 30, pp. 379-406, pls. 25, 26, Dec. 15, 1937. — Delong, Jr., J. H., "The Paleontology and Stratigraphy of the Pleistocene at Signal Hill, Long Beach, California," Trans. San Diego Soc. Nat. Hist., Vol. 9, no. 25, pp. 229-252, figs. 1-4, chart, April 30, 1941.

187 Arnold, R., Mem. Calif. Acad. Sci., Vol. 3, p. 58, 1903.

188 For a study of the fauna of these beds see: Clark, Alex, Trans. San Diego Soc. Nat. Hist., Vol. 7, no. 4, pp. 25-42, 1 map, 1 chart, Dec. 19, 1931.— Willett, G., "Additions to Knowledge of the Fossil Invertebrate Fauna of California," Bull. Southern Calif. Acad. Sci., Vol. 36, pt. 2, May-Aug. (issued Sept. 30), 1937, pp. 61-64, pls. 24, 25.

189 Stephens, Frank, "Notes on the Marine Pleistocene Deposits of San Diego County, California," Trans. San Diego Soc. Nat. Hist., Vol. 5, no. 16, pp. 245-256, text fig. 1, Aug. 5, 1929. See p. 254.

The ecologic conditions were probably quite different.

Very fossiliferous Pleistocene beds were formerly exposed at the foot of Twenty-sixth Street in the southeastern part of the City of San Diego, but within the last few years this outcrop has been completely covered with dredgings from San Diego Bay and it is not likely again to be exposed, though it might be encountered in any wells or deep excavations if located nearby.[190]

Arnold (1903, p. 59) described this locality as follows:

"A bluff about eighteen feet high rises from the edge of the bay at the foot of Twenty-sixth street, San Diego, and extends for two or three blocks both toward the east and toward the west from Twenty-sixth street, forming the shore line along this part of the bay. At the base of this bluff, and covered by the water at high tide is a stratum six inches thick made up almost entirely of the upper valves of *Anomia limatula*. No right valves were found in this deposit, and this species seemed to be restricted to this layer. A stratum of fine, yellow fossiliferous sand, four or five feet thick, rests upon the *Anomia* beds; and above the fossiliferous bed is about twelve feet of fine brown sand, overlain by sandy soil. *Dosinia ponderosa*, *Callista newcombiana*, *Mactra californica*, and *Cardium procerum* are the predominating species in the yellow sand stratum. The fauna of this locality is equivalent to that of the upper San Pedro series at San Pedro."

The most diagnostic species in these beds are *Dosinia ponderosa*, *Cardium procerum*, and *Anomia limatula*. Stephens has described this old locality in his paper on the Pleistocene deposits of San Diego County to which reference has already been made.

Stephens briefly described a number of other Pleistocene fossil localities in San Diego County, from the Mexican Border to as far north as the San Dieguito Valley. One on the shore of Mission Bay (formerly False Bay) is of particular interest because the shells form what is almost a coquina.

Stephens (1929, p. 253) described this locality as follows:

"Crown Point, formerly known as Bay Point, projects into Mission Bay from the north. Along the west side of its southern extremity is a deposit of Pleistocene age. This is a cemented mass composed principally of *Donax laevigata*, with a few *Amiantis callosa*, *Chione succincta*, *Macoma secta*, *Paphia staminea* and *Tivela stultorum* scattered through the mass. In the lower part, at about high tide line, *Dendraster excentricus* is common. The shell-bearing strata extend from the water ten or fifteen feet up the bank."

The name Bay Point formation was recently proposed for these beds by the authors.[191]

From this deposit the late Professor Junius Henderson collected a specimen of *Mellita longifissa* Michelin. The *Dendraster* reported by Stephens as *excentricus* is apparently *diegoensis* Kew. The abundance of *Donax gouldii* (*laevigata*) suggests a correlation with the Spanish Bight Pleistocene, and the fossils at both localities appear to indicate an open clean sandy beach.

All of these localities mentioned above, together with the Spanish Bight locality described below, are probably essentially of the same age, although their faunas differ somewhat, due in all likelihood to differences of ecology. A unique bed consisting almost entirely of a compact mass of *Ostrea lurida* Carpenter, investigated by Stephens and the present authors a few years ago, occurs on the eastern (bay) side of Point Loma along Rosecrans Street near Dumas Street. This oyster bed is also exposed at the southwest corner of Rosecrans and Curtis Streets and it may have been more extensively exposed before the construction of residences in this neighborhood. This is mentioned by Stephens in his Pleistocene paper. It may represent a very shallow or brackish water facies of the upper Pleistocene. Some distance north of this bed, (Loc. No. 70, S.D.S.N.H.), at the northeast end of Point Loma, there formerly existed a little shelf upon which rested a few Pleistocene shells, including among them the distinctive warm water Mexican gastropod, *Turritella gonostoma broderipiana* d'Orbigny. This latter bed is perhaps somewhat different in age from the veneer of Pleistocene shells occurring on a low terrace on the west side of Point Loma from the "Coal Mine" locality, briefly described by Berry[192] and by Stephens (1929, pp. 252-253) and which formed the basis of a longer faunal report by Webb.[193]

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190 C. R. Orcutt mentioned a number of species encountered in excavations in what are now business sections of San Diego. See West Amer. Scientist, Vol. 11, Whole No. 84, pp. 15-16, Jan., 1900; Vol. 11, no. 4, Whole No. 89, pp. 36-38, May, 1900.

191 Hertlein, L. G., and Grant, IV, U. S., Calif. Journ. Mines and Geol., Vol. 35, no. 1, 35th Rept. Calif. State Mineralogist, p. 71, Jan., 1939, [received at the library of the California Academy of Sciences Aug. 23, 1939].

192 Berry, S .S., Proc. Calif. Acad. Sci., Ser. 4, Vol. 11, no. 18, pp. 412-414, May 16, 1922.

193 Webb, R. W., "Paleontology of the Pleistocene of Point Loma, San Diego County, California," Trans. San Diego Soc. Nat. Hist., Vol. 8, no. 24, pp. 337-348, 1937.

The species in the latter locality are not very different from those of the Recent fauna in this same region and do not definitely suggest any significant climatic change.

The Pleistocene beds which have yielded the largest number of species occur on the west side of Spanish Bight. This exposure is now partly obscured by slumping of the beds and by discarded materials thrown over the cliff.

Arnold (1903, p. 59) described this locality as follows:

"The western shore-line of this inlet is a bluff varying in height from twelve to eighteen feet, while the stratum at the base of the bluff forms the beach, and is covered by the water at high tide. This lowest layer is composed of a firm, fine brown sand in which are imbedded numerous large *Amiantis callosa*, which have the appearance of living shells, so naturally do they lie on the sand. An attempt to remove them, however, dispels the delusion, for in most cases they are quite firmly imbedded in the sand layer.

"There are three feet of fine, soft unfossiliferous gray sand above the *Amiantis* layer, and this is overlain by a deposit, varying in thickness from three to five feet, of soft gray sand, which is very fossiliferous near its base and gradually grades into the almost unfossiliferous gray sand a few feet above. About twelve feet from the base of the bluff is a layer from three to six inches thick containing numerous *Donax laevigata* cemented together. This Donax layer is the uppermost fossiliferous stratum, the bluff above this being composed of unfossiliferous sands. The fauna of the Spanish Bight deposits is similar to that of the upper San Pedro series at Los Cerritos, and the deposits are probably of contemporaneous origin."

Mrs. Kate Stephens, Curator Emeritus of Marine Invertebrates, San Diego Society of Natural History, has collected and identified a large number of species from the Spanish Bight Pleistocene deposits. We include here a list of species from this locality identified by Mrs. Stephens:

PELECYPODA

Aligena cerritensis Arnold
Amiantis callosa Conrad
Amiantis callosa Conrad var.
Anomia limatula Dall
Anomia peruviana d'Orbigny
Apolymetis biangulata Carpenter
Arca possibly *gradata* Broderip & Sowerby
Callithaca tenerrima Carpenter
Cardium procerum Sowerby
Cardium quadragenarium Conrad
Cardium substriatum Conrad
Chione gnidia Broderip & Sowerby
Cooperella subdiaphana Carpenter
Corbula luteola Carpenter
Crassinella branneri Arnold
Crassinella varians Dall
Cryptomya californica Conrad
Cumingia lamellosa Sowerby
Diplodonta sericata Reeve
Diplodonta subquadrata Carpenter
Donax californica Conrad
Donax gouldii Dall
Donax punctatostriata Hanley
Glans carpenteri Lamy
Glycymeris sp. (very small)
Kellia laperousii Deshayes
Lucina approximata Dall
Lucina nuttalli Conrad
Lucina tenuisculpta Carpenter
Macoma indentata tenuirostris Dall
Macoma nasuta Conrad
Macoma secta Conrad
Macoma yoldiformis Carpenter
Mactra californica Conrad
Mactra exoleta Gray
Mactra nasuta Gould
Modiolus rectus Conrad
Nucula suprastriata Carpenter
Nuculana taphria Dall
Ostrea sp. (rare)
Pandora punctata Conrad
Panope generosa Gould (one hinge only)
Pecten delosi Arnold
Pecten latiauratus Conrad
Pecten latiauratus monotimeris Conrad
Periploma planiuscula Sowerby
Petricola carditoides Conrad
Petricola cognata C. B. Adams
Pholadidea rostrata Valenciennes
Protothaca staminea Conrad
Psephidia lordi Baird
Rochefortia tumida Carpenter
Schizothaerus nuttallii Conrad
Semele decisa Conrad
Semele pulchra Sowerby
Septifer bifurcatus Conrad
Siliqua lucida Conrad
Solen rosaceus Carpenter
Spisula catilliformis Conrad
Spisula falcata Gould
Spisula planulata Conrad
Tagelus californianus Conrad
Tagelus dombeyi Lamarck
Tagelus subteres Conrad
Tellina bodegensis Hinds
Tellina buttoni Dall
Tellina meropsis Dall
Transennella tantilla Gould
Yoldia cooperii Gabb

SCAPHOPODA

Cadulus californicus? Pilsbry & Sharp
Dentalium neohexagonum Sharp & Pilsbry
Dentalium pretiosum Sowerby
Dentalium semipolitum Broderip & Sowerby

GASTROPODA

Acanthina spirata Blainville
Acmaea depicta Hinds
Acmaea incessa Hinds
Acmaea scabra Gould
Acteocina carinata Carpenter
Acteocina culcitella Gould
Acteocina eximia Baird
Acteocina inculta Gould
Acteon punctocaelata Carpenter
Acteon punctocaelata coronadoensis Stearns
Acteon traskii Stearns
Aesopus chrysalloideus Carpenter
Aesopus oldroydi Arnold
Aesopus sanctus Dall
Aesopus sp.
Alvania compacta Carpenter
Amphissa columbiana Dall
Amphissa versicolor Dall
Barleeia californica Bartsch
Bivonia compacta Carpenter
Bursa californica Hinds
Bulla gouldiana Pilsbry
Caecum californicum Dall
Calliostoma gemmulatum Carpenter
Calliostoma supragranosum Carpenter
Calliostoma tricolor Gabb
Cerithidea californica Haldemann
Cerithiopsis arnoldi Bartsch
Cerithiopsis williamsoni Arnold
Clathrodrillia incisa ophioderma Dall
Clathrodrillia rhines Dall
Conus californicus Hinds
Conus californicus fossilis T. S. Oldroyd
Crepidula aculeata Gmelin
Crepidula adunca Sowerby
Crepidula excavata Broderip
Crepidula lessoni Broderip
Crepidula lingulata Gould
Crepidula onyx Sowerby
Crucibulum spinosum Sowerby
Cylichnella alba Brown
Cymatosyrinx empyrosia Dall
Cymatosyrinx halocydne Dall
Cymatosyrinx hemphilli Stearns
Cytharella densilineata Dall
Delphinula coronadoensis Arnold
Diodora murina (Carpenter MS.) Dall
Epitonium indianorum Carpenter
Erato columbella Menke
Eupleura muriciformis Broderip
Fartulum occidentale Bartsch
Forreria belcheri Hinds (one young shell)
Haliotis fulgens Philippi
Halistylus subpupoideus Tryon
Hipponix antiquatus cranioides Carpenter
Homalopoma carpenteri Pilsbry
Homalopoma lurida Dall
Lacuna compacta Carpenter
Lacuna marmorata olla Dall
Liotia acuticostata Carpenter
Littorina scutulata Gould
Lottia gigantea Gray
Mangelia barbarensis I. S. Oldroyd
Mangelia interlirata Stearns
Mangelia striosa C. B. Adams
Margarites acuticostatus Carpenter
Marginella californica Tomlin
Marginella subtrigona Carpenter
Megasurcula carpenteriana Gabb
Melampus olivaceus Carpenter
Melanella hastata Sowerby
Melanella micans Carpenter
Melanella oldroydi Bartsch
Melanella rutila Carpenter
Metaxia diadema Bartsch
Micranellum crebricinctum Carpenter
Mitrella carinata Hinds
Mitrella gausapata Gould
Nassarius cerritensis Arnold
Nassarius cooperi Forbes
Nassarius fossatus Gould
Nassarius mendicus Gould
Nassarius perpinguis Hinds
Nassarius tegulus Reeve
Natica russa Gould
Norrisia norrisii Sowerby
Odostomia fetella Dall & Bartsch
Odostomia gravida Gould
Odostomia pedroana Dall & Bartsch
Odostomia sevilla Dall & Bartsch
Odostomia tersa T. S. Oldroyd
Odostomia (*Odostomia*) sp.
Olivella baetica diegoensis T. S. Oldroyd
Olivella biplicata angelena T. S. Oldroyd
Olivella biplicata parva T. S. Oldroyd
Olivella pedroana Conrad
Olivella porteri Dall
Phasianella pulloides Carpenter
Phasianella typica Dall
Polinices reclusianus Deshayes
Purpura festiva Hinds
Rissoina pleistocena Bartsch
Seila montereyensis Bartsch
Syncera translucens Carpenter
Tegula ligulata Menke
Tritonalia interfossa clathrata Stearns
Tritonalia interfossa minor Dall
Tritonalia lurida Middendorff
Tritonalia michaeli Ford
Trophon stuarti praecursor Arnold

Truncatella californica Pfeiffer
Truncatella stimpsoni Stearns
Turbonilla acra? Dall & Bartsch
Turbonilla ambusta Dall & Bartsch
Turbonilla arnoldi Dall & Bartsch
Turbonilla asser Dall & Bartsch
Turbonilla attrita Dall & Bartsch
Turbonilla auricoma Dall & Bartsch
Turbonilla buttoni Dall & Bartsch
Turbonilla carpenteri Broderip & Sowerby
Turbonilla laminata Carpenter
Turbonilla pecora T. S. Oldroyd
Turbonilla stearnsii Dall & Bartsch
Turbonilla tenuicula Gould
Volvulella californica Dall
Volvulella cooperi Dall
Volvulella cylindrica Carpenter

AMPHINEURA

Ischnochiton conspicuus Carpenter
Ischnochiton pectinulatus Carpenter

In addition to the fossils reported from the Pleistocene of Spanish Bight by Mrs. Stephens, Mr. S. A. Glassell of Beverley Hills, California, has compiled for us the following list of fossil crabs from this locality:

CRUSTACEA

Callianassa longimana Stimpson
Callianassa stephensi Rathbun
Cancer anthonyi Rathbun
Cancer gracilis Dana
Cancer jordani Rathbun
Hemigrapsus nudus Dana
Hepatus lineatus Rathbun
Heterocrypta occidentalis Dana
Libinia setosa Lockington
Portunus (*Portunus*) *xantusii* Stimpson
Pugettia richii Dana
Pyromaia tuberculata Lockington
Randallia ornata Randall

Mr. Glassell informs us that of this assemblage of 13 species one, *Callianassa stephensi* Rathbun,[194] is extinct. It has also been recorded from Nob Hill (lumber yard) northeast of San Pedro, in the lower San Pedro formation, and at Signal Hill (or Los Cerritos), northeast of Long Beach, California, in the upper San Pedro formation, upper Pleistocene. Two of the species, *Hepatus lineatus* Rathbun (which also occurs in the Pleistocene of Signal Hill), and *Libinia setosa* Lockington (also known in the Pleistocene of Santa Monica), now live in more southern latitudes. Apparently they are unknown north of Cedros Island, Lower California, Mexico, and they are more common farther south. The other species live in the waters off San Diego, California. In general this assemblage of crabs indicates a depth of water of from low tide to 10 fathoms.

The evidence in regard to the temperature and depth of water offered by the crabs is in harmony with that offered by the mollusks at Spanish Bight.

A specimen of a *Camelops* was discovered by Mr. Frank B. Tolman on the west side of Point Loma in beds of Pleistocene age. It was found about 80 feet above tide and 100 yards back of the beach in somewhat indurated clay. This is Locality 126, S.D.S.N.H., and was described by Frank Stephens as occurring about two miles north of the Point Loma Lighthouse, at the mouth of a ravine that heads in the hills, and nearly opposite Fort Rosecrans. The ravine has cut into the Cretaceous or Eocene a few feet and then ends at the sea cliff. The Pleistocene fossiliferous strata are exposed on both sides of the ravine, the lower beds being unusually thick and containing an abundance of small shells. As usual the littoral front is solid rock with no beach. The contact is at an altitude of about 50 feet, and 40 feet below the surface of the mesa.

Regarding the specimen of *Camelops* Dr. Chester Stock has supplied the following statement:

"The specimen you refer to is a small jaw fragment of the right ramus containing two deciduous teeth, representing a young animal. The material is not well preserved, but shows some resemblance to the comparable parts in *Camelops hesternus* from Rancho La Brea."

Many years ago a fossil horse tooth was obtained at a depth of 110 feet in a well at Coronado. This was mentioned by C. R. Orcutt in the West American Scientist.[195]

[194] *Callianassa stephensi* Rathbun, U. S. Nat. Mus., Bull. 138, p. 122, pl. 18, figs. 5-8, 1926. "Spanish Bight, San Diego Bay; upper San Pedro formation, Pleistocene series." Also cited from other localities.

[195] Orcutt, C. R., West. Amer. Sci., Vol. 7, Whole No. 51, p. 24, July, 1890. "When the Coronado Beach Co. were boring an artesian well on Coronado Beach, San Diego, in 1886, a fossil tooth was found at a depth of 110 feet which was presented by H. L. Story to Mrs. R. S. Eigenmann. This has been examined by Prof. E. D. Cope, editor of the American Naturalist, who identifies it as a left upper molar of an extinct species of horse, *Equus excelsus*." (See also, Ellis, 1919, p. 64).

In summary, it can be said that so far as known the marine Pleistocene in the vicinity of San Diego is of late Pleistocene age or at least represents a part of the upper half of that epoch. All the faunas indicate relatively shallow water, probably from tide level to a hundred feet or thereabouts. Such species as *Donax gouldii* Dall (cited as *Donax laevigata* Deshayes by earlier authors) are rather sharply restricted in their habitat to sandy beaches between tides, and *Amiantis callosa* Conrad, *Conus californicus* Hinds, and several others are now commonly found in very shallow water, from low tide to possibly fifty fathoms. There are no species which indicate with certainty a greater depth. This shallow water aspect is in harmony with the conditions of deposition reflected in the sediments, nearly all of which are sands or gravels and broken shell fragments, often lenticular or cross-bedded.

All of the marine fossiliferous Pleistocene deposits which we have examined in this region lie unconformably upon older rocks and have a horizontal attitude or only very low dips. They vary in thickness from a thin veneer, such as at the "Old Coal Mine" locality on Point Loma, to twenty or more feet, such as at Indian Point (foot of Twenty-sixth Street). Most of the deposits are but relatively few feet above sea level although the Pleistocene localities at Torrey Pines and near Del Mar are about 60 feet above tide level according to Stephens.

The climatic significance of the Pleistocene faunas of the San Diego region taken as a whole, and exclusive of the "Coal Mine" Pleistocene veneer, can be interpreted in part by a correlation of the Recent geographic ranges of the species occurring in the Pleistocene with the shallow water sea temperatures prevailing within those ranges. Species which are confined in their bathymetric range to relatively shallow water and are intolerant to a wide range of temperature are the best for this purpose. For example, *Chione gnidia*,[196] which is a shallow water venerid, ranges in the Recent faunas only as far north as Cedros Island (so far as known) where the mean annual sea surface temperature is about 63° F., but it ranges far south, apparently to Paita, Peru; so that its metropolis is no doubt within a zone of water over 65° F., possibly 70° F., at the surface. Thus the presence of this species in the Pleistocene of Spanish Bight, in the embankment on the east shore of Mission Bay,[197] and in the Pleistocene of Clark's Well, Encinitas, is indicative of warmer marine waters in the San Diegan region during a part of the Pleistocene. *Dosinia ponderosa* was reported to range north to San Diego by Dall, but it is apparently unknown living north of Scammon's Lagoon, approximately where the mean annual sea surface temperature along the shore of Lower California is about 65°. This species is present in the Pleistocene of Indian Point (foot of Twenty-sixth Street). A smooth form of *Turritella gonostoma* Valenciennes was collected from the Pleistocene at the north end of Point Loma[198] by Mr. Stephens and the authors. This is another warm water west Mexican mollusk unknown living north of Scammon's Lagoon, and the smooth variety (*broderipiana* d'Orbigny) occurring fossil at Point Loma may be restricted to still more southern waters.

A consideration of the best available data[199] on marine sea-surface temperatures and the approximate near shore positions of the mean annual sea-surface isotherms along the west American coast indicates how much shifting geographically of these temperature conditions might have taken place since the deposition of the San Diego marine Pleistocene deposits. For example, the mean annual sea-surface temperatures near shore along the west American coast appear to be as follows:

Coast of Washington	49° to 53° F.
Cape Blanco, Oregon	50° F.
California coast north of Cape Mendocino	51° F.
Marin County	53° F.

196 This warm water species has been identified by Dall from three localities in the Pleistocene some distance north of San Diego, Calif. These localities are as follows: NE ¼ sec. 36, T. 11 S., R. 5 W., at an elevation of about 70 feet above sea level; old beach ridge at the top of the cliffs 2 miles north of Del Mar; half a mile west of El Salto in a small deposit of dark loam. (See Ellis, 1919, p. 69). *Chione gnidia* is definitely known to occur in the upper Pleistocene Palos Verdes (Upper San Pedro) formation, in the San Pedro region and in the Palisades north of Santa Monica, Calif.

197 Loc. 64, S. D. S. N. H., See Stephens, F., Trans. San Diego Soc. Nat. Hist., Vol. 5, no. 16, p. 253, 1929

198 Locality 70, S. D. S. N. H.

199 We are grateful to Professor George F. McEwen of the Scripps Institution of Oceanography, to the late Dr. R. S. Patton of the U. S. Coast and Geodetic Survey, and to Mr. W. L. Scofield, Supervisor of the California Fisheries Laboratory at Terminal Island, California, for many marine temperature records.

San Mateo County	54° F.
Just south of Point Pinos	55° F.
Point Conception	57° F.
Santa Barbara	58° F.
San Pedro	61° F.
San Diego	62° F.
Cedros Island, Lower California, Mexico	63° F.
San Ignacio Lagoon	65° F.
Just north of Magdalena Bay	68° F.
Just south of Magdalena Bay	69° F.
Just north of Cape San Lucas	75° F.

It appears from this that the San Diego Pleistocene faunas containing *Chione gnidia, Cardium procerum, Dosinia ponderosa* and *Turritella gonostoma broderipiana* represent a shift northward of 250 or 300 miles, or perhaps more.

The authors do not wish to give the impression that they consider the mean annual sea water temperatures to be the only controlling factor in the distribution of these mollusks. It is quite probable that the monthly distribution of temperatures, the times and magnitudes of sudden or slow fluctuations, the temperatures during the spawning season, etc., are effective in limiting the geographical distribution of these species, not to mention the host of other non-thermal factors which determine their ranges. With very limited facts available on the many obscure phases of ecology, the mean annual temperature is merely the most convenient set of conditions to use at the present time.

E. K. Jordan,[200] Hertlein[201] and Palmer and Hertlein[202] have described marine Pleistocene molluscan faunas from several localities along the coast of Lower California, including San Quintin, San Ignacio Lagoon, Magdalena Bay, and Maria Madre Island and Maria Magdalena Island of the Tres Marias Group, and from Oaxaca, Mexico. The beds containing these faunas were considered to be approximately equivalent at least in part to the warm water upper Pleistocene of San Diego, California.

---

[200] Jordan, E. K., "Molluscan Fauna of the Pleistocene of San Quintin Bay, Lower California," Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, no. 7, pp. 241-255, 1 text fig., 1 pl., April 26, 1926. See also, "The Geology of San Quintin Bay," by G. E. Manger, Johns Hopkins Univ. Studies in Geol., no. 11, pp. 273-303, 1 pl., 1934. — Jordan, E. K., "The Pleistocene Fauna of Magdalena Bay, Lower California," Contrib. Dept. Geol. Stanford Univ., Vol. 1, no. 4, 72 pp., 3 pls., 1936.

[201] Hertlein, L. G., "Pleistocene Mollusks from the Tres Marias Islands, Cedros Island, and San Ignacio Lagoon, Mexico," Bull. Southern Calif. Acad. Sci., Vol. 33, pt. 2, May-Aug. [issued Aug. 31], 1934, pp. 59-73, 1 pl.

[202] Palmer, R. H., and Hertlein, L. G., "Marine Pleistocene Mollusks from Oaxaca, Mexico," Bull. Southern Calif Acad. Sci., Vol. 35, pt. 2, May-Aug. [issued Sept. 10], 1936, pp. 65-81, 2 pls

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PHYSIOGRAPHIIC BLOCK DIAGRAM OF THE SAN DIEGO AND LA JOLLA QUADRANGLES AND SOME OF THE MOUNTAINOUS REGION TO THE EAST

(DRAWN BY E. H. QUAYLE)

Portion of a chart of San Diego Bay issued by the U. S. Coast Survey in 1859 showing the course of the San Diego River into San Diego Bay and the old bed of San Diego River leading into False Bay (now known as Mission Bay). The meridians of longitude on this chart are about 6,000 feet too far west and the parallels of latitude are about 615 feet too far north according to the 1927 North American Datum. (Original chart loaned by Mr. S. A. Glassell)

Portion of U. S. Coast and Geodetic Survey Air Photo Compilation charts Nos. T 5373 and T 5374 (date of original photographs 1933). The shore line is that of Mean Lower Low Water. A comparison of this chart with the chart of 1859 shown on Plate 1 illustrates the many changes which have taken place in this area, especially the growth of the delta in Mission Bay. (1927 North American Datum)

Aerial view of the San Diego Mesa looking south across Mission Valley. This illustrates the flat-topped mesa upon which some of the city of San Diego has been built. The obscure contact between the Eocene and the Pliocene sedimentary beds occurs on the slopes of the south side of Mission Valley near the top of the mesa. (Photo by H. A. Erickson).

FIG. 1. View looking north up canyon tributary to San Diego River about [illegible] and about one-half mile east of San Diego River. This view [illegible] which V-shaped canyons have been cut by the present stream.

FIG. 2. View in Balboa Park, San Diego, showing the flat surface of the San Diego Mesa. The sharp edge of the mesa at the top of the canyon side is due to the hard capping of the Sweitzer formation. (Photo by L. M. Huey)

FIG. 1. Terraces south of the flood plain of the Tia Juana River [illegible] boundary Monument 258 and just east of sandy beach. Pliocene fossils o[illegible] ght hand center of picture. (Photo, 1937)

FIG. 2. The Avondale Terrace on south side of Otay Valley. View south from about one mile east of Otay (Photo, 1937).

FIG. 1. Prairie mounds on mesa top about 1¼ miles west of Sweetwater Reservoir. This view shows the mounds extending over the edge of the mesa into the upper part of a small canyon

FIG. 2. Prairie mounds on terrace about one-eighth mile north of Paradise Valley, east of National City (Photo, 1937).

FIG. 1. Igneous and metamorphic rocks exposed at Sweetwater Dam. View east from near [illegible] with Pliocene sediment. The conical peak in the background is San Miguel Mountain. (Photo, 19[illegible]

FIG. 2. Characteristic outcrop of pre-Tertiary igneous rocks exposed as a small island surrounded by Pliocene sediment. View near Aloha, west of Sweetwater Dam

FIG. 1. Characteristic exposure of Rose Canyon shale member of the La Jolla formation on the east side of Rose Canyon about one mile above its mouth. These Eocene beds are approximately horizontal, except those at extreme right near Santa Fe Railway bridge, which have a steep northerly dip. (Photo, 1939).

FIG. 2. The Eocene-Pliocene-Pleistocene contacts in the bluff at the north end of Pacific Beach. The Pliocene sandstone of the San Diego formation is coarser grained, more pebbly and thicker bedded than the underlying Eocene. Contacts emphasized by black lines. (Photo, 1939).

FIG. 1. View looking north at Pacific Beach, showing the well bedded Eocene sediments overlain by Pliocene basal conglomerate in upper right corner. (Photo, 1928)

FIG. 2. Pliocene basal conglomerate overlying Eocene beds at Pacific Beach. At this locality, the dip and strike of the Eocene and the Pliocene beds are nearly the same. (Photo, 1928)

FIG. 1. View looking south at Pacific Beach, showing typical exposure of Pliocene fossiliferous sandstones The Pliocene is here unconformably overlain by fossiliferous Pleistocene sands and gravel. (Photo, 1928)

FIG. 2. Outcrop of hard stratum of coarse sandstone on low spur of mesa between northeast tributaries of Paradise Valley. This is an uncommon lithologic facies of the San Diego Pliocene. (Photo, 1938)

FIG. 1. Fossiliferous Pliocene sandstone on north side of Market Street Extension one-tenth mile east of Euclid Avenue, San Diego. *Pecten subdolus* and other Pliocene mollusks occur here. (Photo, 1938)

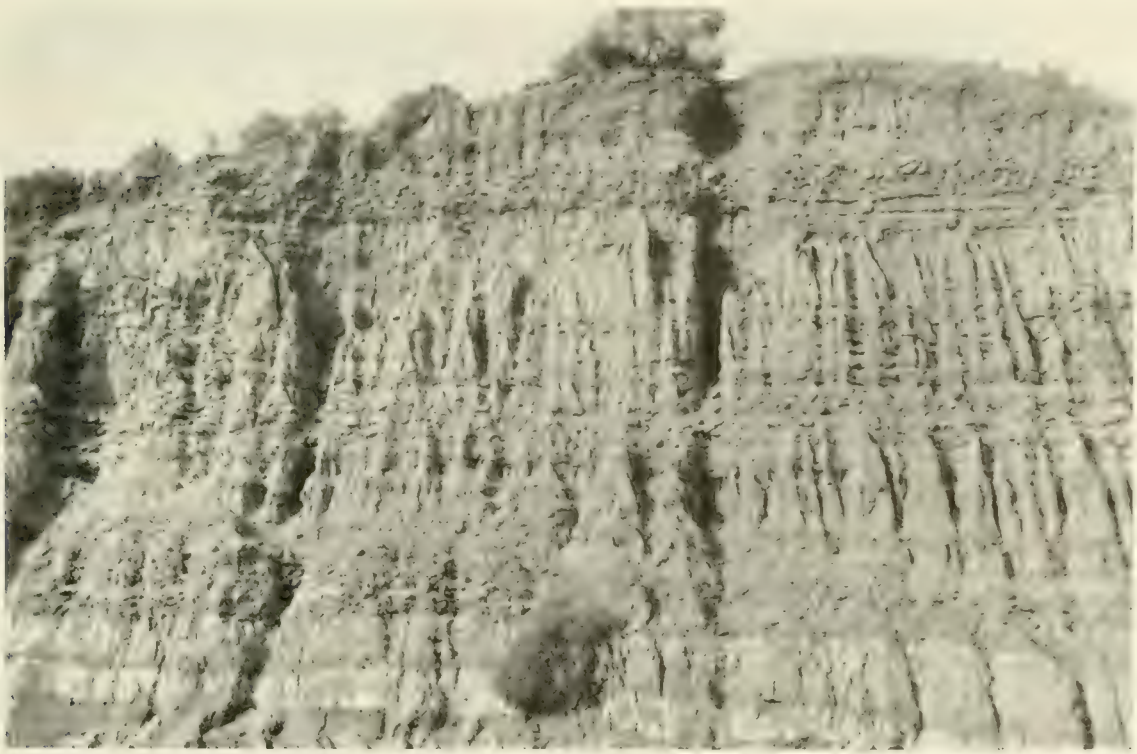

FIG. 2. Conglomeratic yellowish and grayish micaceous Pliocene sandstone and two light colored limy beds exposed on north side of Euclid Avenue about one mile south of University Avenue. Large barnacles occur just above the bush near the base of the cliff. The uppermost five or six feet can be referred to the Sweitzer formation. (Photo, 1938).

Embankment in side of canyon in Balboa Park, San Diego, showing reddish-brown conglomerate and sandstone of the Sweitzer formation disconformably overlying the light gray sandstone of the San Diego formation. Point of hammer indicates the contact. (Photo by L. M. Huey).

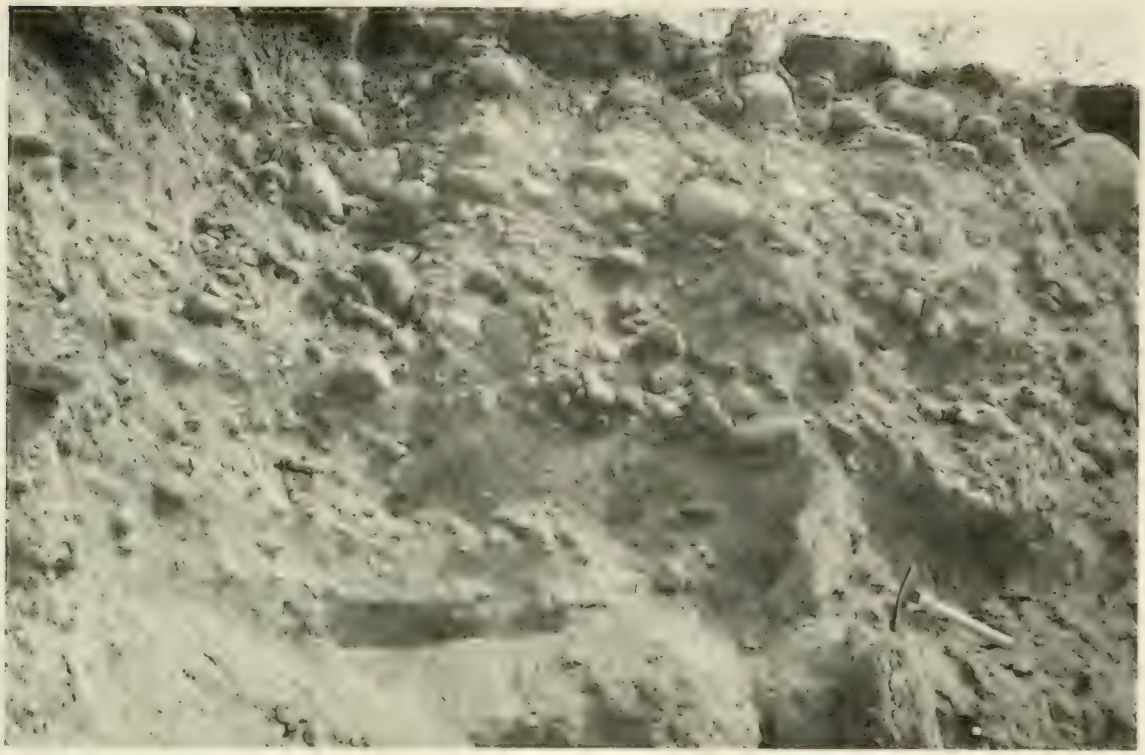

FIG. 1. Reddish-brown coarse sand and conglomerate of the Sweitzer formation overlying the finer lighter colored sands of the San Diego formation. Point of hammer is on contact. View in excavation near top of Otay Mesa on West Park Avenue, 1.55 miles northeast from highway at San Ysidro. (Photo, 1937)

FIG. 2. Pebbly sandy conglomerate of the Sweitzer formation overlying fine light gray sands of the San Diego Pliocene formation on Richmond Street Extension in a tributary of Cabrillo Canyon, Balboa Park. The contact is clearly shown by the contrast in colors. (Photo, 1937)

FIG. 1. Fossiliferous light gray coarse-grained cross bedded Pleistocene sands on the west side of Bay Point (Crown Point), southeast of Pacific Beach. This is the type locality of the Bay Point formation. The aeolian fine-grained sand which forms the subdued dune-like surface of Bay Point overlies these marine Pleistocene beds. (Photo, 1937)

FIG. 2. Nearer view of beds of the Bay Point formation shown in figure 1 showing cross bedding *Dendraster* and *Donax* are very abundant in these beds. (Photo, 1937).

FIG. 1. View eastward from northeastern low spur of Point Loma across Ingraham Street (Mission Bay Causeway) at intersection with Point Loma Boulevard. The gently curving San Diego River dike on the delta flat between San Diego Bay and Mission Bay is shown in t[illegible] in the right background. (Photo. 1938)

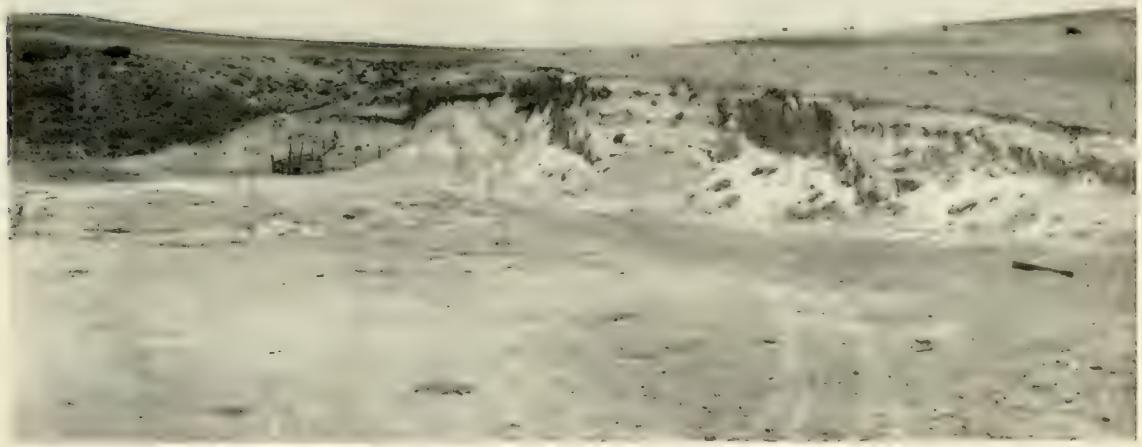

FIG. 2. Bentonite quarry on north side of Otay Valley about two miles east of Otay. The clay layers are interbedded with the Pliocene white sands of the San Diego formation.

Typical exposure of Sweitzer formation on Pershing Drive, Balboa Park, San Diego. (Photo, 1929, by L. M. Huey)

Aerial view southeastward from a position over Pacific Beach showing the delta of the San Diego River between Mission Bay in the foreground and San Diego Bay in the background. The broad rounded promontory in the foreground is Bay Point (Crown Point). The low hilly land in the right middle ground is the northeastern part of Point Loma. A portion of the City of San Diego is shown at the left. The mountains forming the skyline are in Lower California, Mexico. (Photo, 1927, by H. A. Erickson)

FIG 1 Aerial view southward of mesa lands along the United States-Mexico International Boundary from the Pacific Ocean easterly about 3½ miles Part of flood plain of Tia Juana River shown in foreground, partly dissected mesa of Pliocene rocks in middle and background Matadero Canyon shown in center *Pecten healeyi* was obtained from a well located in this canyon indicated by the letter A A second Pliocene fossil locality farther west is indicated by the letter B. Note the apparent alignment of a small eastern tributary of Matadero Canyon with a larger tributary of the next canyon to the west. This is suggestive of a fault which, if present, would pass just north of International Boundary Monument No. 257

(Composite of oblique airphotographs by Erickson 1930 The International Boundary is located south of the fossil localities designated by A and B)

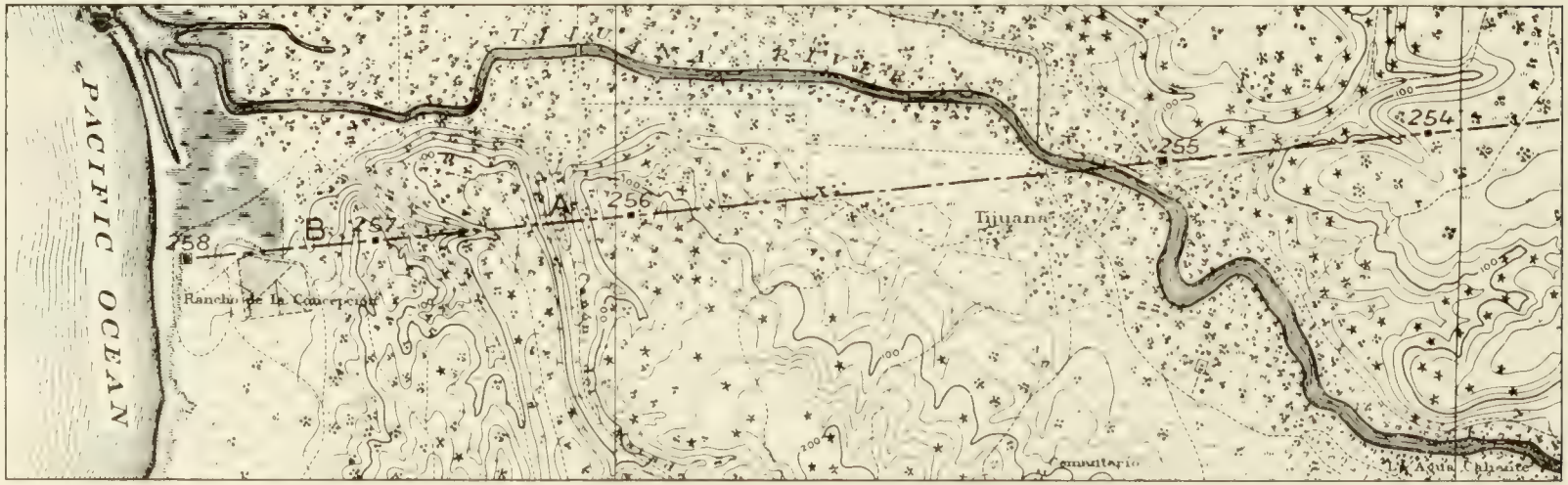

FIG. 2. Contour map of a portion of the area along the United States-Mexico International Boundary showing the location of the two fossil localities indicated by the letters A and B in the accompanying air view Map reproduced from Boundary between the United States and Mexico as surveyed and marked by the International Boundary Commission under the convention of July 29 1882 revised February 18th 1889 Folio Atlas of maps and profiles 21½ by 28¾ inches (Fifty-fifth Congress 2nd Session Senate Doc No 247 Atlas) Published 1898 The map reproduced is the western portion of Map No. 1. Contour interval 20 metres; datum is mean sea level.

(Pacific Ocean shown at left. The aerial view above is in reversed position because the camera was pointed southward)

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Volume II

THE GEOLOGY AND PALEONTOLOGY OF THE MARINE PLIOCENE OF SAN DIEGO, CALIFORNIA

PART 2a, PALEONTOLOGY

(COELENTERATA, BRYOZOA, BRACHIOPODA, ECHINODERMATA)

BY

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FOREWORD

Part 1 of this memoir, issued August 30, 1944, contains a description of the general geology of the San Diego region. The present part begins the systematic account of the Pliocene fossils of this region, treating four phyla. Further experience in the field and laboratory has added to our knowledge much that can be used to advantage in the portions of this work dealing with paleontologic collections, their relationships, and their significance. We therefore hope that an improvement in presentation will compensate for the delay in publication.

Since the appearance of Part 1, geological field work in the San Diego region, chiefly accomplished or instigated by Professor E. Dean Milow, San Diego State College, has brought to light some further details of structure. These details will be discussed more fully in a concluding portion of the memoir, but three of them should be mentioned now. (1) The Soledad anticline is faulted and structurally more complex than originally assumed. (2) The Mission Valley fault, indicated in our text figure (page 50 in Part 1) as a hypothetical one, seems to have received some confirmation in the discovery of a down-faulted wedge of Pliocene strata just north of the mouth of the valley. (3) Some windows of Eocene sediments, identified from studies of microfossils, occur in the bottoms of some of the canyons in, north of, and northeast of Balboa Park where our map indicated Pliocene. These small Eocene windows are difficult to detect because of the lithologic similarity and the slight difference in dip between the Eocene and Pliocene sediments.

A recent treatise on the archaeology of the San Diego region by Professor George F. Carter[1], containing a discussion of the many terraces, may be of interest to the student of physiography or of the Pleistocene and Recent history of that area. Professor Carter believed that the terraces record eustatic changes of sea level rather than intermittent diastrophic uplifts.

ACKNOWLEDGMENTS

Many individuals have aided us during the preparation of this paper. Acknowledgment is made to some of them in the text. Special acknowledgment is due Dr. G. Dallas Hanna, Curator, Department of Geology, California Academy of Sciences, and Mr. Allyn G. Smith, Research Malacologist in the same institution, who have aided and advised the authors on many occasions. Likewise, Miss Veronica Sexton and Mr. Ignatius M'Guire of the library staff of the California Academy of Sciences have aided the authors on many occasions with reference work and in securing needed literature. Mr. Alan E. Leviton, Department of Herpetology, contributed valuable criticism concerning the section dealing with classification and nomenclature. Dr. J. Wyatt Durham, Associate Professor of Paleontology, University of California at Berkeley, identified specimens of corals for us, and Dr. John W. Wells, Cornell University, and Dr. Donald F. Squires, American Museum of Natural History, furnished information concerning certain species of this class. Some of the Bryozoa mentioned in the present paper were identified by Dr. R. S. Bassler of the United States National Museum. Later, the same specimens and additional ones were identified by Dr. John D. Soule, Allan Hancock Foundation, University of Southern California. Mr. Fred C. Ziesenhenne of the same institution aided in the identification of some of the fossil echinoderms and furnished important information after comparing them with Recent specimens.

We especially wish to acknowledge the courtesy of Mr. George P. Kanakoff, Curator of the Department of Invertebrate Paleontology, Los Angeles County Museum, who lent us a fine series of exceptionally well-prepared corals, bryozoa, brachiopods, and echinoids, which were collected from the San Diego formation. Dr. Hildegarde Howard of the same institution approved and facilitated the loan.

Fossils from the San Diego formation in the collections of the San Diego Society of Natural History were lent us by Kate Stephens, late Curator of Marine Invertebrates; and Mr. Emery P. Chace, present Curator, lent additional specimens and aided in other ways. Dr. William K. Emerson, formerly

(1) Carter, G. F., "Pleistocene Man at San Diego," (Johns Hopkins Press, Baltimore), pp. 1-400, 6 tables, 96 figs., 1957.

Museum Paleontologist in the Department of Paleontology at the University of California, Berkeley, California, (now with the American Museum of Natural History in New York), made available collections in that institution, checked certain references for us, and aided us in various ways. Mr. Edwin C. Allison and Mr. Joseph H. Peck, Jr., Museum Paleontologists in the same department, likewise aided us whenever called upon for information. Dr. Hubert G. Schenck and Dr. A. M. Keen have given us free access to the collections in the Department of Geology at Stanford University, and Dr. Willis P. Popenoe and Mr. Takeo Susuki, Department of Geology at the University of California at Los Angeles, made available the collections of that institution. Professor E. Dean Milow, San Diego State College, furnished specimens of fossils from the San Diego formation as well as information concerning certain localities in that area. Some specimens in the United States National Museum which were collected by Henry Hemphill from the San Diego well, were lent us by Dr. Paul Bartsch, Curator of the Division of Mollusks in the National Museum. Later, Dr. G. A. Cooper in the same institution lent specimens of fossil brachiopods from Cedros Island, Lower California, Mexico, and from southern California.

The following individuals aided us in furnishing information concerning type specimens in their respective institutions: Dr. Ruth Turner and Dr. Elizabeth Deichmann, Museum of Comparative Zoology, Harvard University; Mr. Percy A. Morris, Peabody Museum of Natural History, Yale University; Dr. Leslie R. Cox and Dr. Helen M. Muir-Wood, British Museum (Natural History), London; Dr. André Franc, Museum National d'Histoire Naturelle in Paris. Dr. M. H. deLaubenfels, Oregon State College, examined several specimens to ascertain whether these were bored by sponges. Mr. Robert Lando, formerly a resident of San Diego, made available a manuscript containing the results of his study of Recent and fossil mollusks at San Diego. The illustrations used in the plates are from photographs made by Mr. Charles E. Crompton, Photographer, California Academy of Sciences.

CLASSIFICATION AND NOMENCLATURE

The ideal natural classification of all organisms would group together closely related forms and separate those that are distantly or not related. Phylogeny, therefore, should be the fundamental basis of a natural system of classification of all organisms. All modern systematists no doubt agree on this point. They do not agree, however, concerning the significance and interpretation of the various taxonomic categories. Disagreements arise because the use of different characters leads to differences in classification. Furthermore, the use of a few large inclusive groups by one systematist conflicts with the use of more numerous finely divided, narrowly restricted groups by another systematist. Added to these disagreements, the application of the International Rules of Zoological Nomenclature frequently leads to complex legal questions which are variously interpreted by different authors or disregarded entirely by others: even decisions of the Commission may be reversed by the Commission at a subsequent meeting. This unfortunate state of affairs has led to much confusion, much argumentative literature, and an altogether lamentable expenditure of time and effort without actually adding much that is fundamental to our knowledge of nature. Consequently, in view of the present-day unsatisfactory condition of paleontologic systematics, it seems desirable at the beginning of this portion of the memoir that its authors express their viewpoints concerning nomenclature.

The authors subscribe to the general application of the International Rules of Zoological Nomenclature and most particularly to the rule of priority, which they are convinced is the cornerstone of these rules. They have deviated from this rule only rarely and only where a long-established and well-known name cannot be employed through strict adherence to this rule. Some of these well-known names later may be validated either by a suspension of the rules (as in the case of the recent validation of *Modiolus* Lamarck, 1799, replacing the earlier *Volsella* Scopoli, 1777) or through application of the "Principle of Conservation" (Internat. Rules Zool. Nomencl., 1953, pp. 119-122). Suspension of the rules, however, does not always stabilize nomenclature. Nicol[2] pointed out that in one case such action resulted in the

(2) Nicol, D., Jour. Washington Acad. Sci., Vol. 40, No. 3, p. 82, March 15, 1950. See also McKerrow, W. S., "Fossil Species and the Rules of Nomenclature" [in] "The Species Concept in Palaeontology" (P. C. Sylvester-Bradley, editor), Systematics Association, Publ. No. 2, p. 122, 1956.

necessity for a change of the name of a well known genus (the replacement of *Corbis* Cuvier by *Fimbria* Megerle von Mühlfeld).

In the differentiation of genera and species, dependence has been placed upon a totality of characters, where possible, rather than upon one character. Characters of the shells and of other hard parts that are preserved as fossils are given more emphasis than those of soft parts that can be studied only in living material — and sometimes are given exclusive mention. Although the anatomy of soft parts is very important in systematic zoology, traces of these are rarely preserved in rocks; and the paleontologist must rely on what is usually preserved.

In the treatment of species, a more definite and objective concept than that of the genus, it is hoped that an intermediate logical course has been followed, characterized neither by excessive "splitting" nor by excessive "lumping." The authors do not believe in naming new forms unless these are distinguished by characters that appear relatively constant, but they are fully aware of the need of fine stratigraphic delimitation of species based upon objective characters, no matter how small the differences may be.

Recognition of these species, whose stratigraphic ranges are often narrowly limited, is very useful in determining chronological sequence of strata. Also important in deciphering the earth's history are some closely similar forms separated by great stratigraphic range, which may represent a long time interval.

The paleobiologist emphasizes continuity within phylogenetic lineages of biologic forms by which their evolution may be understood. The paleontologist, on the other hand, while recognizing the importance of the phylogenetic sequence, looks especially for the breaks in the sequence which permit the recognition of distinct morphological units whose geologic ranges are frequently short. On the basis of such units, paleontologists are able to assign an age to and to correlate strata deposited approximately contemporaneously. The viewpoint of the paleontologist has been ably presented by Weller[3].

One of the most important aims of all paleontological work is the interpretation of the fossil record. Precise correlation of strata, interpretation of the conditions under which these strata were deposited, and elaboration of the geological history of local basins and provinces, should result in a knowledge of the history of continents and oceanic basins.

For the ultimate aim to be more quickly realized, it is important to compare species and genera that are now far separated geographically and to seek possible relationships. For this reason the authors have here and there called attention to foreign species or to larger groups which are similar in morphology to the local forms and which may later be discovered to have had a common origin. Such discoveries may have an important bearing on inter-regional migration and geologic history. The excessive splitting of genera and species and the resulting multiplication of names are often based either on characteristics whose stability and importance are unknown or on the mere assumption that geographically distant forms cannot be closely related. This practice may obscure natural relationships and indefinitely delay the recognition of inter-regional relationships. It appears that the provincial attitude of some systematists has, to an extent, concealed intercontinental faunal relationships[4] and thus made more difficult the work of students of world history as a whole.

The authors have given considerable thought to the general arrangement of the information accompanying each species in this monograph. The type locality, the depository of the type specimen, the geologic and geographic range of the species, and its occurrence in the Pliocene strata of southwestern San Diego County, should certainly be included. The original descriptions are included for the convenience of the reader because many of the publications in which they appeared are rare and, to many workers, not readily accessible.

Specific names printed in boldface type are for species which we have identified in the fauna of the San Diego formation in or near San Diego and which we consider to be valid members of that fauna. Specific names printed in standard type and enclosed in brackets [ ] are for species which have been

(3) Weller, J. M., "Paleontologist-Biologist and Geologist," Jour. Paleo., Vol. 22, No. 2, pp. 268-269, March, 1948.

(4) See remarks by C. A. Fleming (Trans. Roy. Soc. New Zealand, Vol. 79, Pt. 1, p. 128, 1951) concerning subgenera of *Pecten*. Also, "The Genus Pecten in New Zealand," New Zealand Geol. Surv., Paleo. Bull. 26, pp. 7-10, 1957.

reported from the San Diego formation in or near San Diego but of which we have not seen specimens. These we consider to be doubtful or invalid members of the fauna.

Species whose records of occurrence in the San Diego formation are equivocal, such as "San Diego-Purisima,"[5] are not included in the present paper unless substantiated by specimens or by published records definitely referable to the San Diego beds.

The references in the synonymy of the species, in general, have been restricted to the one containing the original description, to those containing illustrations of the type specimen (or of typical specimens), and to those in which the species is cited as occurring in Pliocene strata in the San Diego area. We also have included some references which, although not citing the species from the San Diego formation, contain information especially useful to others interested in the present faunal study. Additional references pertinent to the general discussion of the species are placed as footnotes. This system of citation of references is in general similar to that in the work of Anderson and Hanna[6].

Descriptions of families, genera, and subgenera are followed by the name of the author and the date when taken from works cited in the synonymy. Otherwise, the author and reference are cited. Where the author is not cited, the descriptions have been drawn up by the present authors. Some of the descriptions of the families and genera of Echinoidea in this work are taken verbatim from the excellent catalogue by H. L. Clark[7].

The systematic treatment of phyla of which we have made no special study is restricted to a brief summary based upon the literature, or upon information furnished us by others where so indicated in the text. A study of the Foraminifera has been entrusted to others and, if completed in time, it will be included in this memoir.

ABBREVIATIONS

Abbreviations following locality numbers or specimen numbers refer to the following institutions:

(ANSP) — Academy of Natural Sciences of Philadelphia.

(CAS) — California Academy of Sciences.

(LAM) — Los Angeles County Museum Invertebrate Paleontology.

(SD) — San Diego Society of Natural History.

(SU) — Stanford University.

(UC) — University of California (Berkeley).

(UCLA) — University of California at Los Angeles.

(USGS) — United States Geological Survey.

(USNM) — United States National Museum.

(5) See Smith, J. P., "Geologic Range of Miocene Invertebrate Fossils of California," Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 161-182, April 5, 1912.

(6) Anderson, F. M., and Hanna, G. D., "Fauna and Stratigraphic Relations of the Tejon Eocene at the Type Locality in Kern County, California," Occ. Papers Calif. Acad. Sci., No. 11, pp. 1-249, pls. 1-16, figs 1-10 in text, March 18, 1925.

(7) Clark, H. L., "A Catalogue of the Recent Sea-Urchins (Echinoidea) in the Collection of the British Museum (Natural History)", (London), pp. i-xxviii, 1-250, pls. I-XII, 1925.

SYSTEMATIC DESCRIPTIONS

Phylum **COELENTERATA** Frey and Leuckart

Class **ANTHOZOA** Ehrenberg

Corals occur only rarely in Pliocene strata of California except in Imperial County, from which region seven species and five varieties were described by Vaughan[8]. In 1903, Vaughan described *Caryophyllia californica*[9] from supposedly Pliocene beds at San Pedro, California, which are now generally considered Pleistocene. *Astrangia coalingensis* Vaughan[10] was cited and illustrated in 1910 from strata now known to be of Pliocene age in San Joaquin Valley.

Nomland[11] in 1916 recorded seven species from the Pliocene of California and Oregon. Durham recorded one species[12] from the Pliocene of San Joaquin County, California, another [13] from probable late Pliocene in Humboldt County, and a third[14] from the Pliocene of Carmen Island in the Gulf of California. Durham[15] summarized the ranges of genera of fossil corals occurring in that region. More recently Durham and Barnard[16] dealt with the Recent species of stony corals of west American waters. The Order Scleractinia was treated by Vaughan and Wells[17] in 1943 and by Wells[18] in 1956.

The papers mentioned above contain additional references to literature dealing with corals which need not be mentioned here. Five genera, each represented by a single species, are known to occur in Pliocene beds in southwestern San Diego County.

Order **SCLERACTINIA** Bourne

Suborder **FAVIINA** Vaughan and Wells

Family **OCULINIDAE** Gray

Colonial; colony formation by extratentacular (or rarely intratentacular) budding. Corallites externally thickened by extensive, noncostate, granulated or smooth, dense (rarely vesicular) coenosteum. Septa exsert, formed by one fan system of simple trabeculae, margins minutely dentate, laterally granulose or spinose. Pali generally developed. Columella papillose, trabecular, or absent. Endothecal dissepiments, when developed, subtabular, thin, or replaced by stereome. (Wells, 1956.) Cretaceous to Recent.

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(8) Vaughan, T. W., "The Reef-Coral Fauna of Carrizo Creek, Imperial County, California, and its Significance," U.S. Geol. Surv., Prof. Paper 98-T, pp. 355-376, figs. 43-46, pls. 92-102, March 3, 1917.

(9) *Caryophyllia californica* Vaughan in Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 87, pl. 3, figs. 2, 2a, June 27, 1903. "Deadman Island, off San Pedro, California." "Geologic Horizon.—Pliocene."

(10) *Astrangia coalingensis* Vaughan in Arnold, U.S. Geol. Surv., Bull. 396, pp. 30, 34, 152, pl. 23, fig. 3, 1909 (issued January 15, 1910.

(11) Nomland, J. O., "Corals from the Cretaceous and Tertiary of California and Oregon," Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 5, pp. 59-76, pls. 3-6, January 20, 1916.

(12) Durham, J. W., "A New Coral from the Pliocene of California," Jour. Paleo., Vol. 15, No. 3, pp. 278-279, figs. 1, 1a, 2, May, 1941.

(13) Durham, J.W., "Pacific Coast Tertiary and Cretaceous Corals," Jour. Paleo., Vol. 17, No. 2, pp. 196-202, figs. 1, 2, pl. 32, March, 1943.

(14) Durham, J. W., "1940 E. W. Scripps Cruise to the Gulf of California. Megascopic Paleontology and Marine Stratigraphy," Geol. Soc. America, Mem. 43, Pt. 2, pp. i-viii, 1-216, figs. 1-3, pls. 1-48, tables 1-10, August 10, 1950.

(15) Durham, J. W., "Corals from the Gulf of California and the North Pacific Coast of America," Geol. Soc. America, Mem. 20, pp. i-v, 1-68, figs. 1, 2, pls. 1-14, March 26, 1947. [A paper by D. F. Squires dealing with corals from the Gulf of California appeared recently (Bull. Amer. Mus. Nat. Hist., Vol. 118, Art. 7, pp. 367-432, text figs. 1-20, pls. 28-34, October 26, 1959).]

(16) Durham, J. W., and Barnard, J. L., "Stony Corals of the Eastern Pacific Collected by the Velero III and Velero IV," Allan Hancock Pac. Exped., Vol. 16, No. 1, pp. 1-110, pls. 1-16, August 18, 1952.

(17) Vaughan, T. W., and Wells, J. W., "Revision of the Suborders Families, and Genera of the Scleractinia," Geol. Soc. America, Spec. Paper No. 44, pp. i-xv, 1-363, figs. 1-39, pls. 1-51, tables 1-3, March 12, 1943.

(18) Wells, J. W., "Scleractinia," Treatise on Invertebrate Paleontology (Geol. Soc. America and the Univ. Kansas), Part F, Coelenterata, pp. F328-444, figs. 222-339, 1956.

Genus **ARCHOHELIA** Vaughan

Archohelia Vaughan, U.S. Nat. Mus., Bull. 103, Pt. 9, p. 352, July 11, 1919. "Type-species. —*Archohelia limonensis* Vaughan." —Vaughan and Wells, Geol. Soc. America, Spec. Paper No. 44, p. 181, March 12, 1943. "Genotype (original designation): *A. limonensis* Vaughan 1919."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Pt. F, Coelenterata, p. F411, 1956. Type indicated as *A. limonensis* Vaughan.

TYPE SPECIES (by original designation): *Archohelia limonensis* Vaughan, 1919, p. 353, pl. 80, figs. 1, 1a, 1b, 2, 3. Cotypes from "Niveau *d*, Moin Hill, Port Limon," Costa Rica. "The geologic horizon seems to be Pliocene."

RANGE: Middle Cretaceous to late Pliocene. Atlantic and eastern Pacific.

ORIGINAL DESCRIPTION: *Archohelia* differs from *Oculina* solely by having a persistent axial corallite, whereas in *Oculina* there is no axial corallite. Pali or paliform teeth are present on all but the last cycle of septa. Columella trabecular, with some papillae on its upper surface. (Vaughan.)

REMARKS: Vaughan remarked that several Tertiary species of the eastern United States, which were referred to "*Astrohelia*"[19] Milne Edwards and Haime and to *Oculina* Lamarck, should be placed in *Archohelia*. About ten species of this genus are known.

Durham (1947, p. 7) indicated that the genus *Archohelia* occurs from Eocene to Miocene in the western United States. The present record from the San Diego formation extends the range of the genus into late Pliocene time in southern California.

Archohelia species

One well-preserved specimen of a coral and some imperfect ones were collected from Pliocene strata at Pacific Beach by Frank B. Tolman and the late Ernest H. Quayle. These were found in a light buff fossiliferous pebbly sandstone layer, 4 to 6 inches thick, 10 feet stratigraphically above the Eocene-Pliocene contact, just north of the mouth of the ravine cutting the terrace two hundred feet south of the lowest exposure of the contact. The beds also contained specimens of *Opalia*, echinoid spines, and Bryozoa.

A manuscript in our possession contains a description by Quayle of this coral. We have searched in vain for the specimens and illustrations of the Pliocene species described by Quayle. Lacking these we have reluctantly decided not to publish the description which he prepared. It is our conclusion that there can only be uncertainty concerning the identity of a species based upon a description but lacking specimens and illustrations.

Quayle considered this coral to be a new species of *Oculina* Lamarck, closely resembling *O. peruviana* Vaughan[20], an Eocene species from Peru.

He also compared it with *O. panzana* Loel and Corey[21], from early Miocene strata in San Luis Obispo County, California. After discussing Quayle's description with Dr. J. W. Durham, we agree with him that Quayle's coral probably is referable to *Archohelia* rather than to *Oculina*.

Family **RHIZANGIIDAE** d'Orbigny
(=*Astrangiidae* Verrill)

Colonial, ahermatypic. Colony formation by extratentacular budding from edge zone or stolon-like expansions of edge zone, polyps remaining organically connected or not, colonies commonly consisting of scattered corallites with no apparent connection, or united basally by coenosteum, or they form compact masses. Corallites small and low. Septa composed of one fan system of simple or compound trabeculae; irregular divergence of sclerodermites producing scattered lateral granulations and more or less irregular marginal dentations. Columella trabecular, rarely solid or absent. Endothecal dissepiments thin. (Wells, 1956.) Early Cretaceous to Recent.

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(19) The original spelling of this genus name is *Astrhelia*.

(20) *Oculina peruviana* Vaughan, in Bosworth, T.O., "Geology of the Tertiary and Quaternary Periods in the North-West Part of Peru," (Macmillan & Co., London), p. 127, pl. 21, figs. 2-5, 1922. "Near Negritos; Clavilithes Series," Eocene.

(21) *Oculina panzana* Loel and Corey, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 22, No. 3, p. 275, pl. 65, figs. 1-3, December 31, 1932. "Vaqueros horizon, Lower Miocene only. Known only from the type locality, Carrizo Creek, west of the Carrizo ranch house, south end La Panza Mountains."

Genus **ASTRANGIA** Milne Edwards and Haime

Astrangia Milne Edwards and Haime, Comptes-Rendu Acad. Sci. Paris, Vol. 27, p. 496, November, 1848. No species cited. —Vaughan and Wells, Geol Soc. America, Spec. Paper No. 44, p. 177, 1943. "Genotype (Genolectotype, Milne Edwards and Haime, 1850): *A. michelini* Milne Edwards and Haime 1848."—Durham, Geol. Soc. America, Mem. 20, p. 25, 1947. "Genotype: *Astrangia michelinii* Milne Edwards and Haime."—Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 60, 1952. "Genotype: *Astrangia michelinni* Milne Edwards and Haime."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F408, 1956. Type indicated as *A. michelini* Milne Edwards and Haime.

TYPE SPECIES (designated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Monogr. British Fossil Corals, Introduction, p. xliv, 1850): *Astrangia michelini* Milne Edwards and Haime. [Ann. Sci. Nat. Zool., Ser. 3, Vol. 12, p. 181, September, 1849. "Patria inconnue.—Coll. Michelin." For this species the authors cited Vol. 10, pl. 7, figs. 4, 4a, August, 1848. In the explanation to plate 7, however, these figures are referred to "*Oulangia Stokesiana*"; and in volume 12, *Oulangia stokesiana* is cited on page 183, also with reference to Vol. 10, pl. 7, figs. 4, 4a. "Habite les Philippines (H. Cuming). —Coll. Stokes."]

RANGE: Middle Cretaceous to Recent. In the western United States, Oligocene to Recent. Recent in North, Central, and South America and the West Indies.

ORIGINAL DESCRIPTION: *G. Astrangia.* Diffère du genre précédent [*Rhizangia*] en ce que les polypiérites sont toujours unis entre eux par le base que est etalée, et que leur muraille est nue. (Milne Edwards and Haime.)

SUPPLEMENTARY DESCRIPTION: Encrusting, subplocoid, corallites united basally by thin peritheca, rarely solitary. All septa dentate. Columella papillary. Epitheca rarely developed. (Vaughan and Wells, 1943.)

REMARKS: The genus *Astrangia* is known to occur from Oligocene to Recent in western North America. Twenty-one species of this genus have been recorded from marine waters between San Luis Obispo Bay, California, and Zorritos, Peru, from the littoral zone to 91.5 meters (50 fathoms). Only one of these species occurs off southern California; the remainder occur in tropical and subtropical waters.

Astrangia coalingensis Vaughan was described from beds of late Pliocene age in the southern portion of the San Joaquin Valley, and *A. insignifica* Nomland was described from beds of late Pliocene age in Los Angeles. Several specimens questionably identified as the latter species were collected in the San Diego formation.

Astrangia cf. **A. insignifica** Nomland

Plate 19, Figures 1-4, 7

The following is a reference to typical *A. insignifica.*

Astrangia insignifica Nomland, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 5, p. 65, pl. 3, figs. 14, 15, January 20, 1916.

TYPE SPECIMEN: No. 12010, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "in upper Fernando formation, Pliocene, at corner of Fourth and Broadway streets, Los Angeles, California."

RANGE: Middle Pliocene in southern California.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

ORIGINAL DESCRIPTION: 'The material at hand consists of a single corroded specimen of slightly elliptical outline. It appears to have been connected to other corallites by a thin basal expansion. No costae are visible; this may perhaps be due to the worn condition of the specimen. Calice shallow. Septa in four cycles, thick, granulate, those of the third cycle fused to the second; the septa of the fourth cycle very small. Columella well developed, vesicular. Altitude of corallite, 2 mm.; maximum latitude, 8.3 mm. (Nomland.)

REMARKS: Six specimens belonging to the genus *Astrangia* were collected by G. P. Kanakoff at Loc. 305 (LAM), in the San Diego formation near the Mexican boundary. These specimens were examined by Dr. J. W. Durham, who identified them tentatively with *Astrangia insignifica* Nomland.

One specimen is 3 mm. high and its calice is 3.2 mm. in diameter. Another is 2.5 mm. high and the diameter of its calice approximately 4.3 mm. The type specimen of that species is not perfectly preserved, but according to Durham (1947, p. 29), there appear to be about 48 septa. The present specimens appear to have about the same number.

In addition to the original occurrence, *Astrangia insignifica* has been recorded by Soper and Grant[22] from late Pliocene strata at 5th and Hope streets in Los Angeles, California.

The imperfect state of preservation of the type specimen of *Astrangia insignifica* and the consequent uncertainty concerning some of its specific characters led Durham to describe somewhat similar specimens of a Recent coral from Ensenada, Lower California, under the name of *Astrangia lajollaensis*[23]. It is known to occur from San Luis Obispo Bay, California, to Santa Margarita Island, Lower California, Mexico, from shore to a depth of 53 meters (29 fathoms).

Suborder **CARYOPHYLLIINA** Vaughan and Wells

Family **CARYOPHYLLIIDAE** Gray

Solitary and colonial. Colony formation by extratentacular (rarely intratentacular) budding, forming phaceloid or dendroid colonies. Costae commonly covered by stereome or epitheca. Septa exsert. Columella formed by curled trabecular laths, solid, spongy or absent. Pali or paliform lobes common. Endothecal dissepiments developed in some groups. (Wells, 1956.) Jurassic to Recent.

Genus **PARACYATHUS** Milne Edwards and Haime

Paracyathus Milne Edwards and Haime, Ann. Sci. Nat., Ser. 3, Vol. 9, p. 318, May, 1848. Species cited: *Paracyathus stokesii* Milne Edwards and Haime, *P. desnoyersii* Milne Edwards and Haime, *P. procumbens* Milne Edwards and Haime, *P. aequilamellosus* Milne Edwards and Haime, *P. pedemontanus* Michelin, *P. turonensis* Milne Edwards and Haime, *P. caryophyllus* Lamarck, *P. brevis* Milne Edwards and Haime.—Vaughan and Wells, Geol. Soc. America, Spec. Paper No. 44, p. 206, 1943. "Genotype (genolectotype, Milne Edwards and Haime 1850): *P. procumbens* Milne Edwards and Haime, 1848. Eocene (Parisian). Hauteville (la Manche)."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F424, 1956. Type indicated as *Paracyathus procumbens* Milne Edwards and Haime.

TYPE SPECIES (designated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Monograph of British Corals, Introduction, p. xv): "Typ. sp., *Paracyathus procumbens,* Milne Edw. and J. Haime, loc. cit., tab. x, fig. 6" [Ann. Sci. Nat., Ser. 3, Vol. 9, p. 320, pl. 10, figs. 6, 6a, 6b, May, 1848. "Fossile d'Hauteville." Eocene.]

RANGE: Eocene to Recent. Cosmopolitan. Bathymetric range, 13 to 1472 meters (7 to 805 fathoms). (Vaughan and Wells.)

DESCRIPTION: Solitary, turbinate, fixed. Pali opposite all but last cycle, merging with columellar papillae. (Wells.)

REMARKS: Corals of this genus are attached whereas *Heterocyathus* Milne Edwards and Haime and *Deltocyathus* Milne Edwards and Haime, also solitary, are free forms.

According to Vaughan and Wells about 40 species of *Paracyathus* are known. Three species have been described as fossils from west American Tertiary strata, and six species have been described as occurring in west American waters at the present time.

Paracyathus stearnsii Verrill

Plate 19, Figures 8-13

Paracyathus stearnsii Verrill, Proc. Boston Soc. Nat. Hist., Vol. 12, p. 393, May, 1869.—Durham, Geol. Soc. America, Mem. 20, p. 35, pl. 2, figs. 1, 2, 5, 6, March 26, 1947. Skidegate Inlet, Queen Charlotte Islands, British Columbia, to San Pedro, California, Recent.—Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 92, pl. 13, figs. 55a-e, August 18, 1952. Numerous records cited, British Columbia to Dewey Channel, Lower California, Recent.

TYPE SPECIMEN: Location unknown to the present authors.

TYPE LOCALITY: "Monterey, California; Robert E. C. Stearns."

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[22] Soper, E. K., and Grant, U. S., IV, "Geology and Paleontology of a Portion of Los Angeles, California," Bull. Geol. Soc. America, Vol. 43, No. 4, p. 1064, December 30, 1932.

[23] *Astrangia* (*Astrangia*) *lajollaensis* Durham, Geol. Soc. America, Mem. 20, p. 28, pl. 2, figs. 14, 15, 18, 20, 21, March 26, 1947. "Loc. A-3982 (Ensenada, Lower California, Mexico)." "Collected along beach" (p. 44).

RANGE: Middle Pliocene to Recent. Recent from Skidegate Inlet, Queen Charlotte Islands, British Columbia, to 8½ miles south of Dewey Channel, Lower California (between Natividad Island and Point San Eugenio), in 22 to 894 meters (12 to 489 fathoms); mostly occurring between 27 and 110 meters (15 and 60 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

ORIGINAL DESCRIPTION: Corallum with an expanded base, above which it is somewhat constricted, and then expands rapidly to the edge of the broad, shallow cup, which is broad oval in form, the edge bent into slight lobes or undulations. Exterior with very numerous, prominent, subequal, scabrous costae, which extend from the summit to the outer edge of the base; on the basal portion three or five smaller ones often alternate with one more prominent; toward the summit some of them have a tendency to rise into crests; all are covered with several series of small, sharp granulations, similar to those on the sides of the septa. Five complete cycles of septa, with some small ones in some of the systems belonging to the sixth cycle, so that the whole number is about one hundred and twenty. The primary and secondary septa are considerably broader than the others, broadly rounded and somewhat exsert at summit, narrowed toward the base and divided into two or three unequal, broad, stout, paliform lobes, which are rough and lacerately spinulose at summit, and covered on the sides with coarse rough granulations. The septa of the succeeding cycles are successively narrower, thinner, and less exsert, with similar but smaller, rough, paliform teeth. Columella small, papillose, the papillae slender, prominent, lacerately spinulose at summit.

Height .60; diameter of narrowest part .38 by .50; diameter of cup .50 by .72; depth of cup .25. (Verrill.) [Dimensions in inches.]

REMARKS: A number of specimens, most of them imperfectly preserved, were collected by G. P. Kanakoff at Loc. 305 (LAM), near the Mexican boundary, associated with *Balanophyllia elegans* and *Dendrophyllia* cf. *D. oldroydi*. The specimens were identified by J. W. Durham and appear to be inseparable from the Recent *Paracyathus stearnsii*, which occurs in adjacent waters often at depths of 27 to 110 meters (15 to 60 fathoms). The calice of the largest specimen is 14.8 mm. in greater diameter and 11 mm. in lesser diameter.

Paracyathus stearnsii differs from the Recent *P. tiburonensis*[24] in possessing narrower costae, with fewer and coarser granules on top of the ridge.

The late Pleistocene *Paracyathus pedroënsis* Vaughan[25] was relegated to the synonymy of *P. stearnsii* by Durham and Barnard (1952).

Suborder **DENDROPHYLLIINA** Vaughan and Wells

Family **DENDROPHYLLIIDAE** Gray

Solitary and colonial, mostly ahermatypic. Colony formation by intra- and extratentacular budding. Wall formed by trabecular outer ends of septa and simple but very irregular synapticulae, irregularly porous, usually thick, irregularly costate or covered by reduced costal granulations. Porous, layered coenosteum in some colonial forms. Septa composed of one fan system of simple trabeculae, but trabeculae tend to be very irregular, commonly not united closely in plane of septum and vertically discontinuous with sclerodermites bending outward from septal plane, especially at periphery and near columella. Septa strongly granulated laterally, mostly smooth marginally except peripherally and centrally where irregular dentations occur, or wholly weakly dentate. Septa inserted following Pourtalès plan (Fig. 239), at least in early stages. Columella trabecular and spongy, or absent. Endothecal dissepiments thin and poorly developed. (Wells, 1956.) Late Cretaceous to Recent.

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(24) *Paracyathus tiburonensis* Durham, Geol. Soc. America, Mem. 20, p. 35, pl. 3, figs. 5, 6, March 26, 1947. "Loc. A 3664, depth 73 meters, southwest of Tiburón Island, Gulf of California."

(25) *Paracyathus pedroënsis* Vaughan, in Arnold, Mem Calif. Acad. Sci., Vol. 3, p. 88, pl. 3, figs 1, 1a, June 27, 1903. "San Pedro, California." "Pleistocene." (P. 46, species indicated as occurring at "Lumber Yard," Upper San Pedro, Pleistocene.)

KEY[26] TO THE GENERA OF DENDROPHYLLIIDAE

A. Solitary; corallum trochoid or subcylindrical (curved or straight) ..... *Balanophyllia*

B. Colonial; corallum dendroid; extratentacular budding ..... *Dendrophyllia*

Genus **DENDROPHYLLIA** de Blainville

Dendrophyllia de Blainville, Dict. Sci. Nat., Vol. 60, p. 319, 1830. Species cited (p. 320): *D*[*endrophyllia*]. *ramea* Linnaeus, *D. semiramea* de Haan, *D. cornigera* Lamarck, *D. rubeola* Quoy and Gaimard, *D. digitalis* [Blainville], *D. irregularis* [Blainville], *D. variabilis* [Blainville]. [The latter three species, fossil forms, were attributed to Guettard but since he had cited the species in the French language they are not acceptable in biological nomenclature. Blainville is considered to be the author of these species].—Vaughan and Wells, Geol. Soc. America, Spec. Paper 44, p. 237, March 12, 1943. "Genotype (genolectotype, Milne Edwards and Haime, 1850): *Madrepora ramea* Linnaeus 1758. Recent. Mediterranean and eastern North Atlantic."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F435, 1956. Type indicated as *Madrepora ramea* Linnaeus.

TYPE SPECIES (designated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Monogr. British Fossil Corals, Introduction, p. liii, 1850): "Typ. sp., *Dendrophyllia ramea,* Blainville, loc. cit.; Milne, Edw., Atlas du Règne Animal de Cuvier, Zooph., pl. LXXXIII, fig. 1" [=*Madrepora ramea* Linnaeus, Syst. Nat., ed. 10, p. 797, 1758. "Habitat in O. Americano & Asiatico." Ref. to Pet. Gaz., t.76, fig. 7. — Also illustrated by Schmidt in Brehms Thierleben, ed. 2, Abt. 4, Bd. 2, p. 486, figs. A, B, 1884. — Döderlein, Mitteil. Zool. Station zu Neapel, Bd. 21, No. 5, p. 147, Taf. 9, figs. 90-92, September 6, 1913 (as *Dendrophyllia ramea*). Mediterranean, in 180 to 270 meters (98 to 148 fathoms), Atlantic at Madeira.]

RANGE: Eocene to Recent. Cosmopolitan. Bathymetric range, littoral zone to 1372 meters (0 to 750 fathoms). Temperature range, 11.2-27.3° C. (52-81° F.). (Vaughan and Wells.)

DESCRIPTION: Structures like *Balanophyllia,* but forming dendroid colonies by extratentacular budding from the edge-zone, the polyps remaining organically connected. Columella small. (Vaughan and Wells, 1943.)

REMARKS: About 25 species of this cosmopolitan genus have been described. Three species are known to occur at the present time in west American waters between southern California and the Gulf of California. One of these occurs in beds of Pliocene age in California. Woodring recorded an unidentified species of *Dendrophyllia* in beds of Pliocene age in the Santa Maria district, Santa Barbara County, California.

Dendrophyllia cf. **D. oldroydi** Faustino

Plate 19, Figures 5, 6, 15

The following are references to typical *D. oldroydi.*

Dendrophyllia oldroydi Faustino MS [misspelled Faustina] in I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, No. 1, pl. 49, fig. 7, 1924. [No description.]—Faustino, Philippine Jour. Sci., Vol. 44, No. 3, p. 286, pl. 1, fig. 2, March, 1931. "Sunken Valley, between San Pedro and Redonda [Redondo], California, 200 fathoms; deep water off San Diego, California."—Durham, Geol. Soc. America, Mem. 20, p. 38, pl. 10, figs. 1, 9, March 26, 1947. "200 fms. off San Pedro, Calif. (holotype); numerous records by fishermen from 'deep water' off the Southern California coast; 100 fms. off Huntington Beach, California."

TYPE SPECIMEN: Holotype missing from Stanford University collection. Paratype, No. 5905, Department of Paleontology Type Collection, Stanford University; specimen illustrated by Faustino, 1931 (according to A. M. Keen, oral communication, 1957).

TYPE LOCALITY: "200 fathoms off San Pedro." California.

RANGE: Middle Pliocene to Recent. Recent, off San Pedro to San Diego, California, in 183 to 366 meters (100 to 200 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R. 2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

DESCRIPTION: Colony high and arborescently branched. Two specimens are in the Stanford University collection; one is 30 centimeters high and 38 centimeters across in one direction, the other is 24 centimeters high with branches not so numerous and with a thick base. The branching is irregular and apparently takes place wherever there is opportunity. Budding takes place at the base of the branches and at the sides. The main stem of the first specimen, which is regarded as the type, is 1 centimeter, and

[26] Adapted from Vaughan and Wells, 1943.

the branches are about the same size. The base of the second specimen is 3 centimeters and the main branches 2 centimeters.

The corallites are subcircular, the largest are 1 centimeter in diameter, and project as much as 7 millimeters above the base. Wall perforate, covered externally with fine subequal costal striations, somewhat scabrous, corresponding to all septa. Corallites not very deep, with a jagged edge.

Septa in four complete cycles, often with narrow rudimentary septa corresponding to the fifth cycle. The form and arrangement of the septa are clearly shown in the figure.

Columella well developed, rather prominent, sometimes occupying about a third of the breadth of the corallite, composed of convoluted and contorted porous plates. (Faustino, 1931.)

REMARKS: Two imperfect branching specimens, tentatively assigned to this species, the larger specimen about 19 mm. long, and the larger calice about 10.5 mm. wide, were collected with specimens of *Balanophyllia elegans* Verrill at Loc. 305 (LAM) in southwestern San Diego County. Dr. J. W. Durham, University of California, considered these specimens to be comparable to *Dendrophyllia oldroydi*. The only other record of this species as a fossil is from beds of late Pliocene or early Pleistocene age in Humboldt County, California[27].

The solid character of the corallum, the varyingly exsert septa, the three sizes of costae, and the more rounded calices serve to separate *D. oldroydi* from *D. californica* Durham[28], which was described from off the west coast of Lower California. *Dendrophyllia cortezi* Durham and Barnard[29] was described from "South of Isla Partida, 70 fms." in the Gulf of California, and, according to its authors, "is separated from *D. oldroydi* Faustino by the dentate third cycle septa, by the longer and more slender calices, and by the upper margins of the calices being much less serrate in appearance."

Genus **BALANOPHYLLIA** Searles Wood

Balanophyllia Searles Wood, Ann. and Mag. Nat. Hist., Vol. 13, No. 81, p. 11, January, 1844. Sole species, *Balanophyllia calyculus* Searles Wood.—Vaughan and Wells, Geol. Soc. America, Spec. Paper No. 44, p. 236, March 12, 1943. "Genotype (monotypy): *B. calyculus* Wood 1844."—Durham, Geol. Soc. America, Mem. 20, p. 40, March 26, 1947. "Genotype: *Balanophyllia calyculus* Searles Wood."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F433, 1956. Type indicated as *B. calyculus* Wood.

TYPE SPECIES: (by monotypy): *Balanophyllia calyculus* Searles Wood, Ann. and Mag. Nat. Hist., Vol. 13, No. 81, p. 11, January, 1844. (Ref. to Mag. Nat. Hist., Vol. 3, p. 272, fig. 60d, 1830). "Sutton." "Red Crag." England. [Late Pliocene or Pleistocene]. [Illustrated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Fossil Corals of Great Britain, Corals of the Crag, p. 9, pl. 1, figs. 3, 3a, 3b, 3c, 3d, 1850. Red Crag of Sutton, late Pliocene or early Pleistocene. — Neaverson, Strat. Paleo. (Macmillan and Co.: London), p. 28, fig. 4 (upper right), 1928.]

RANGE: Eocene to Recent. Recent world-wide, at depths of 0-1100 meters (0-601 fathoms) and in temperatures of 6.7-27.7° C. (44-82° F.), according to Vaughan and Wells (1943). In the western Americas from British Columbia to La Plata Island, Ecuador, and the Galapagos Islands, intertidal zone to 605 meters (331 fathoms), usually in about 91 meters (50 fathoms).

DESCRIPTION: Simple, solitary, conical corals, curved or straight, attached by base; septa very numerous, closely crowded and partly fused together; columella spongy; epitheca often present, structure porous; costae on exterior corresponding to the septa. (Adapted from Vaughan and Wells.)

REMARKS: About 50 species of this genus are known according to Vaughan and Wells. Two species have been described from Eocene strata and two from Oligocene strata in western North America. To this record of fossil forms we add the occurrence of a species from beds of Pliocene age in San Diego. Five species of *Balanophyllia* are known to occur at the present time in west American marine waters between British Columbia and Ecuador.

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(27) *Dendrophyllia oldroydi* Faustino?, Durham, Jour. Paleo., Vol. 17, No. 2, p. 201, pl. 32, fig. 1, March, 1943. "Loc. A3770, late Pliocene or Pleistocene of Humboldt County, California. Exposed in road cut along U. S. Highway 101, 1.5 miles north of bridge across Little River at Little River Beach State Park, from a highly fossiliferous gravel lense in loose sand."

(28) *Dendrophyllia californica* Durham, Geol. Soc. America, Mem. 20, p. 37, pl. 10, figs. 2, 6, March 26, 1947. "27°52′ N. Lat., 114°54′45″ W. Long. Taken on a rock cod line in 23 fms."

(29) *Dendrophyllia cortezi* Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 102, pl. 16, figs. 66a, 66b, August 18, 1952.

Balanophyllia elegans Verrill

Plate 19, Figures 14, 19-21; Plate 24, Figures 4, 5, 8, 13, 15-17

Balanophyllia elegans Verrill, Bull. Mus. Comp. Zool., Vol. 1, No. 3, p. 44, January, 1864.—Verrill, Trans. Connecticut Acad. Arts and Sci., Vol. 1, pp. 511-512, pl. 10, fig. 3, 1870. Puget Sound to Monterey, California, Recent.—Durham, Geol. Soc. America, Mem. 20, p. 41, pl. 1, figs. 7, 8, 11, 12; pl. 10, figs. 3, 4, text fig. 2A, 1947. British Columbia to Point Conception and the Channel Islands, California, low tide to 160 fathoms, Recent.—Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 99, pl. 14, figs. 62a-c, 1952. British Columbia to northwest of Cortes Bank, west of San Diego, California, in 36-321 fathoms, Recent.

TYPE SPECIMEN: Location unknown to the present authors.

TYPE LOCALITY: "Crescent City and Mendocino, California; A. Agassiz."

RANGE: Middle Pliocene to Recent. Recent from British Columbia, Canada, to Punta Santo Tomas[30], Lower California, Mexico, intertidal zone to 587 meters (321 fathoms), but usually abundant in less than 91 meters (50 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R. 2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). UNIVERSITY OF CALIFORNIA: Loc. A-8333, same locality as the preceding.

ORIGINAL DESCRIPTION: Corallum attached by a broad base, low, subturbinate. Calyx broad, oval, deep. Epitheca well developed, covering more than half the height of the wall, which is thin and very porous. Septa thin, forming five complete cycles, the principle ones a little exsert, strongly toothed at the summit, finely dentate below; those of the last order unite together near the columella, and are joined near their middle by those of the preceding order; columella porous, little developed. Height, .4 of an inch; greatest diameter of the calyx .48, shortest .4. Color of the living polyp, bright orange. (Verrill.)

REMARKS: Several hundred specimens referable to this species were collected by G. P. Kanakoff at Loc. 305 (LAM), near the Mexican boundary in southwestern San Diego County. The largest is about 20.8 mm. high with a calice 7 mm. in greatest diameter. These are all referable to the Recent species, *Balanophyllia elegans*. Five specimens, the largest 16 mm. in altitude and approximately 7 mm. in diameter, were collected by W. K. Emerson at the same locality (UC A-8333).

Durham (1947, p. 41) mentioned that northern littoral specimens of this species have nearly smooth septa but that the more southern forms in the same habitat have the septa ornamented with coarse granules. He further stated that specimens from deep water are thinner and more fragile, with the epitheca usually not well developed. Durham expressed the opinion (oral communication) that the elongate form of the present specimens might suggest that they lived at depths possibly between 46 and 366 meters (25 and 200 fathoms). Other fossils accompanying these corals suggest that the assemblage lived in comparatively shallow water.

Balanophyllia cedrosensis Durham (1947, p. 40, pl. 11, figs. 3, 5; text fig. 2B), described from near Cedros Island, was said to differ "from *B. elegans* by the greater constriction above the base, by its greater size, larger raised columella, and by the inner edges of all except the first two cycles of septa on *B. elegans* being markedly dentate. On *B. elegans* the septa slope to the floor of the calice, and the columella is not raised."

Vaughan and Wells (1943, p. 86) pointed out the close relationship between *Balanophyllia elegans* in the western Americas and *B. regia* Gosse in British waters, *B. verrucaria* Linnaeus[31] in the Mediterranean, and *B. capensis* Verrill[32] in South Africa.

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(30) Recorded by W. K. Emerson, Jour. Paleo., Vol. 30, No. 2, p. 394, March, 1956.

(31) *Madrepora verrucaria* Linnaeus, Syst. Nat., ed. 10, p. 793, 1758. "Habitat in M. Mediterraneo."—Milne Edwards and Haime, Ann. Sci. Nat., Ser. 3, Vol. 10, p. 85, pl. 1, figs. 6, 6a, August, 1848 (as *Balanophyllia verrucaria*). "Habite la Corse."—Milne Edwards and Haime, Hist. Nat. Corall., Vol. 3, p. 100, 1860 (as *Balanophyllia verrucaria*). "Habite la Corse." [The name of this species was erroneously cited as *"verrucosa"* by Vaughan and Wells].

(32) *Balanophyllia capensis* Verrill, Commun. Essex Inst., Vol. 5, p. 28, pl. 1, fig. 1; pl. 2, figs. 1, 1a, 1866. From Simon's Bay, Cape of Good Hope, 15 to 20 fathoms.

Phylum **BRYOZOA** Ehrenberg

A modern classification of this phylum by Bassler[33] appeared recently. Earlier, Canu and Bassler[34] published a report on late Tertiary and Quaternary Bryozoa of North America.

A number of specimens of Bryozoa were mounted on glass slides by W. D. Rankin during the segregation of foraminifera found in Pliocene strata at Pacific Beach, San Diego. These specimens were submitted to Dr. R. C. Bassler, Head Curator of the Department of Geology, United States National Museum, who kindly identified nine species. Dr. Bassler also identified, as to genus only, *Hippodiplosia* and *Membranipora* collected by the late E. H. Quayle.

Specimens of Bryozoa collected recently by George P. Kanakoff of the Los Angeles County Museum, from Pliocene strata in and near San Diego, were identified by Dr. John D. Soule, Allan Hancock Foundation, University of Southern California. He also studied the material which formed the basis of Bassler's list, finding one additional species, *Parasmittina trispinosa* (Johnston).

Table 1 lists the Pliocene species of Bryozoa from San Diego, as identified by Bassler and by Soule, the nomenclature according to Soule.

Dr. Soule's comments on this assemblage are summarized as follows.

Of the 31 species thus far definitely identified from the San Diego Pliocene, only three are not known in Recent waters. These are *Cheilopora grandis* Canu and Bassler, previously reported from the Eocene, and *Smittina discoidea* Canu and Bassler and *Stathmepora flabellata* Canu and Bassler, both previously listed only from the Pleistocene[35]. Of the remaining 28 species, so far as I know, only the following nine have previously been listed from the Pliocene:

Adeona violacea (Johnston)
Chapperia patula (Hincks)
Colletosia radiata (Moll)
Hippoporella gorgonensis Hastings
Hippothoa hyalina (Linnaeus)
Microporella ciliata (Pallas)
Parasmittina trispinosa (Johnston)
Porella porifera (Hincks)
Schizoporella cornuta (Gabb and Horn)

Of these nine only *Adeona violacea* (Johnston), found in present-day tropical waters, is not listed from the Pleistocene — unless the listing of *Adeona heckelii* Reuss refers to this species. (Canu and Bassler considered *A. violacea* a junior synonym of *A. heckelii;* but both Osborne and I disagree with this conclusion.)

The bathymetric ranges of the 28 Recent species are between low water and 490 meters (268 fathoms), most species occurring in less than 275 meters (150 fathoms).

The Pacific coast of North America south of the polar regions may be divided into three zoogeographical zones: (1) a cool temperate zone from Alaska to Point Conception, California, (2) a warm temperate zone from Point Conception to Magdalena Bay, Lower California, and (3) a tropic zone from Magdalena Bay to about 6° South Latitude. The 28 species of Bryozoa reported from the San Diego Pliocene and still extant have the following zonal distribution:

Hippothoa hyalina and *Parasmittina trispinosa* are truly cosmopolitan: they are found in abundance from the polar regions to tropical waters in both the Atlantic and the Pacific. Three species are exclusively tropical. Nine are tropical, warm temperate, and cool temperate. Ten are only warm and cool temperate. None are only cool temperate or polar. Thus the Pliocene Bryozoan fauna of San Diego appears to have been predominately warm temperate to tropical.

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(33) Bassler, R. S., "Bryozoa," [in] Treatise on Invertebrate Paleontology, (Geol. Soc. America and Univ. Kansas Press), Part G, pp. G1-G253, figs. 1-175, 1953.

(34) Canu, F., and Bassler, R. S., "North American Later Tertiary and Quaternary Bryozoa," U. S. Nat. Mus., Bull. 125, pp. i-vii, 1-302, figs. 1-38, pls. 1-47, July 16, 1923.

(35) See Soule, J. D., and Duff, M. M., "Fossil Bryozoa from the Pleistocene of Southern California," Proc. Calif. Acad. Sci., Ser. 4, Vol. 29, No. 4, pp. 87-146, November 5, 1957.

TABLE 1. PLIOCENE SPECIES OF BRYOZOA FROM SAN DIEGO

	Pacific Beach (CAS)	Loc. 414 (SD)	Loc. 415 (SD)	Loc. 417 (SD)	Loc. 107 (LAM)	Loc. 122 (LAM)	Loc. 305 (LAM)	Pleistocene	Recent
Adeona violacea (Johnston), 1847	.	.	.	.	.	.	x	.	x
Callopora corniculifera (Hincks), 1882	.	.	.	.	.	.	x	x	x
Cellaria diffusa Robertson, 1905	.	.	.	.	.	.	x	x	x
Cellaria mandibulata Hincks, 1882	x	.	.	.	.	.	x	x	x
Chapperia patula (Hincks), 1881	.	.	.	.	.	.	x	x	x
Cheilopora grandis Canu and Bassler, 1920	.	.	.	.	x	x	x	.	.
Coleopora gigantea (Canu and Bassler), 1923	.	.	.	.	.	.	x	x	x
Colletosia radiata (Moll), 1803	.	.	.	.	.	.	x	x	x
Conopeum commensale Kirkpatrick and Metzelaar, 1922	.	.	.	.	.	.	x	x	x
Crisia serrulata Osburn, 1953	x	.	.	.	.	.	.	x	x
Diaperoecia californica (d'Orbigny), 1852	x	.	.	.	.	.	x	x	x
Disporella californica (d'Orbigny), 1852	.	.	.	.	.	.	x	.	x
Eurystomella bilabiata (Hincks), 1882	.	.	.	.	.	.	x	x	x
Heteropora pacifica Borg, 1933	.	.	.	.	.	.	x	.	x
Hippodiplosia sp.	.	x	x	x	.	.	.	.	.
Hippopodinella adpressa (Busk), 1854	.	x	x	.	.	x	x	x	x
Hippoporella gorgonensis Hastings, 1930	.	.	.	.	.	.	x	x	x
Hippothoa hyalina (Linnaeus), 1767	x	.	.	.	.	.	x	x	x
Lagenipora punctulata (Gabb and Horn), 1862	x	.	.	.	.	.	x	x	x
Membranipora sp.	.	x	.	.	.	.	.	.	.
Microporella californica (Busk), 1856	.	x	.	.	.	.	x	x	x
Microporella ciliata (Pallas), 1766	.	.	.	.	.	.	x	x	x
Microporella umbonata (Hincks), 1884	.	.	.	.	.	.	x	x	x
Mucronella major (Hincks), 1884	.	.	.	.	.	.	x	x	x
Parasmittina trispinosa (Johnston), 1825	x	.	.	.	.	.	x	x	x
Penetrantia sp.[36]	.	.	.	.	.	.	x	x	.
Porella porifera (Hincks), 1884	.	.	.	.	.	.	x	x	x
Reginella mucronata (Canu and Bassler), 1923	x	.	.	.	.	.	x	x	x
Rhynchozoon rostratum (Busk), 1856	.	.	.	.	.	.	x	x	x
Schizoporella cornuta (Gabb and Horn), 1862	.	x	.	.	.	.	x	x	x
Smittina discoidea Canu and Bassler, 1923	x	.	.	.	.	.	.	x	.
Stathmepora flabellata Canu and Bassler, 1923	x	.	.	.	.	.	.	x	.
Thalamoporella californica (Levinsen), 1909	.	.	.	.	.	.	x	x	x
Tubulipora tuba (Gabb and Horn), 1862	x	.	.	.	.	.	x	x	x

[36] This record of a ctenostome Bryozoan is based upon galleries riddling fragments of shells to which Bryozoa are attached.

The Bryozoa recorded in the present paper are from the following localities.

CALIFORNIA ACADEMY OF SCIENCES: Pacific Beach; W. D. Rankin, collector.

LOS ANGELES COUNTY MUSEUM:

LOCALITY 107. — 100-foot bluff with scattered concretions, in the clay quarry at the end of Arroyo Drive, San Diego; G. P. Kanakoff, collector.

LOCALITY 122. — 20 to 30 feet below the end of Loring Street, Pacific Beach.

LOCALITY 305. — 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S, R. 2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943); G. P. Kanakoff, collector.

SAN DIEGO SOCIETY OF NATURAL HISTORY:

LOCALITY 414. — Coarse conglomerate layer with a limy matrix, barnacle reef in the first road cut on Euclid Avenue south of University Avenue, where the road curves to the left as it enters Las Chollas Valley, San Diego; E. H. Quayle, collector. [= Loc. 308 (UCLA).]

LOCALITY 415. — Oyster layer in a building excavation at the southeast corner of India and Upas streets, San Diego; E. H. Quayle, collector. [=Loc. 309 (UCLA).]

LOCALITY 417. — The second ravine north of Loc. 331 (SD) and the fifth ravine north (about 1/4 mile north) of the Mexican boundary, at west face of terrace 3/4 mile east of coast, the ravine debouching near the north end of a willow patch. Lower conglomerate well consolidated and richly fossiliferous; E. H. Quayle, collector. [= Loc. 312 (UCLA).]

Phylum **BRACHIOPODA** Duméril

Brachiopoda are known to occur from early Cambrian to Recent. They are primarily shallow-water dwellers, becoming less abundant in deeper water, but they have been recorded from a depth of 5,477 meters (2,995 fathoms). The largest number of species live in the warmer seas.

The west American Cenozoic Brachiopoda have been discussed and illustrated in a monograph by the present authors[37], where references may be found (p. 10) to many of the important works dealing with their classification, morphology, and distribution. The west American Pliocene forms were classified in 3 orders, 5 families, 7 genera, and 20 species and subspecies. Five species and subspecies are represented in the Pliocene strata at San Diego. Many of the late Cenozoic species in western North America are represented by closely related forms in beds of approximately the same age in Japan[38].

Mattox[39] recently discussed the ecologic occurrences of brachiopod communities in the waters about Santa Catalina Island off southern California.

Class **INARTICULATA** Huxley

Order **ATREMATA** Beecher

Superfamily **LINGULACEA** Waagen[40]

Family **LINGULIDAE** Gray

Attenuate, sub-quadrate or spatulate, almost equivalved Lingulacea, with a more or less long, tubular, flexible pedicle. Muscles highly differentiated and consisting of six pairs, two adductors, and four of sliders or adjustors. (Schuchert in Eastman's ed. of Zittel's text-book of Paleo., 1913.) Ordovician to Recent.

Genus **GLOTTIDIA** Dall

Glottidia Dall, Amer. Jour. Conch., Vol. 6, Pt. 2, p. 157, October 6, 1870. "Type. *Glottidia albida,* Dall. Pl. 8, fig. 1-6."—Thomson, New Zealand Board Sci. and Art, Manual No. 7, p. 128, 1927. "Genotype.—*Lingula albida* Hinds," fig. 36 (a, b).—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 10, November 4, 1944. "Type of the genus (by original designation).—*Glottidia albida* Hinds."

TYPE SPECIES (by original designation): *Glottidia albida* Hinds.

RANGE: Late Eocene to Recent. Recent in western America from Monterey Bay, California, to Peru. Also Caribbean.

ORIGINAL DESCRIPTION: Shell linguiform, elongate, pedunculated; general characters as in *Lingula*. Neural valve provided internally with two sharp narrow incurved laminae, diverging from the beak and extending about one-third the length of the shell; anterior extremities of the laminae about

(37) Hertlein, L. G., and Grant, U. S., IV, "The Cenozoic Brachiopoda of Western North America," Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, pp. i-vi, 1-236, figs. 1-34, pls. 1-21, November 4, 1944.

Two later American works dealing with the Brachiopoda as a whole but with emphasis on classification, morphology, and distribution are: Cooper, G. A., [in] "Index Fossils of North America" by Shimer, H. W., and Shrock, R. R., (John Wiley & Sons, Inc., New York), Brachiopoda, pp. 277-365, pls. 105-143, 1944; Moore, R. C., Lalicker, C. G., and Fischer, A. G., "Invertebrate Fossils," (McGraw-Hill Book Co., Inc., New York), Brachiopoda, pp. 197-267, fig. 6(1-40), 1952.

(38) See Hatai, K. M., "The Cenozoic Brachiopoda of Japan," Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, pp. 1-413, pls. 1-12, figs. 1-25, in text, 1940.

(39) Mattox, N., "Observations on the Brachiopod Communities near Santa Catalina Island," Essays in the Natural Sciences in Honor of Captain Allan Hancock on the Occasion of his Birthday July 26, 1955 (Univ. South. Calif. Press, Los Angeles), pp. 73-86, figs. 1-5, November 8, 1955.

(40) Cited as "Superfamily 2. Lingulacea. Waagen" by Schuchert in Eastman's edit. of Zittel's Text-Book of Palaeo., Vol. 1, p. 306, 1896. Waagen (Palaeo. Indica, Ser. 13, Vol. 1, Pt. 4, Fasc. 5, 1885) stated (p. 751), "a suborder for which I shall introduce the name of 'Lingulacea' or 'Mesokaulia'." P. 754, "Sub-Order: Mesokaulia sive Lingulacea." There is also a "Division" Lingulaceae of Bowditch, 1822, and "Fam. 1. *Lingulacea*" of Menke, 1830.

midway between the mesial line and the margin. Haemal valve with a mesial septum of about the same length extending forward from the beak. Anterior adductor impression rounded, separated by a faint mesial ridge, faintly impressed. Scar of the post adductor close in the cavity of the beak, rounded. No other evident scars. Shell smooth, perforate or imperforate. (Dall.)

REMARKS: We can add nothing to Morse's[41] remarks concerning the distinction between *Glottidia* and *Lingula* which follow:

"Aside from the internal structure of the dorsal and ventral shell, the form of the protegulum, the presence of gill ampullae, the arrangement of the oblique muscles, and the more anterior position of the coelomic cavity, I found that in *Glottidia* the setal tubes were not formed, though the lateral setae assume a vertical position when partially buried in the sand, as in *L. lepidula;* the sand tube is much more complete and symmetrical and in alcohol is retained on the peduncle, while in *L. lepidula* the sand tube becomes detached. In general behavior, however, the two forms are almost precisely alike. Charles Schuchert ('97), in considering the enormous period in geological history occupied by the Lingulidae, says the only change observable is that in the ancient forms the viscera occupy a little more and the brachia a somewhat less space than in the later forms. *Glottidia* by these characters is a more ancient type."

Glottidia, so far as known, is confined to the two sides of the Americas. It is known to occur from late Eocene to Recent in the eastern Pacific and from Miocene to Recent in the western Atlantic. Four species have been described living in west American waters and one in the Caribbean. Only one species has been recorded from beds of Pliocene age in western North America.

Schuchert mentioned that inarticulate Brachiopoda of shallow and littoral zones are found in comparatively warm water. The maximum depth at which *Glottidia* has been reported is 110 meters (60 fathoms); but as stated by Schuchert, "the immediate shoreline, and often the estuarine bays and deltas, will be indicated especially by the large lingulids embedded in muds and sands with an otherwise sparse fauna." They are therefore generally considered indicators of shorelines. Morse pointed out that the empty shells of *Glottidia* are delicate and light and unless covered by sediment are likely to be carried away by even a slight current.

Glottidia albida Hinds

Plate 19, Figures 17, 18, 23-25

Lingula albida Hinds, Voy. Sulphur, Zool., Moll., Pt. 3, p. 71, pl. 19, fig. 4, 1844 (date cited as January, 1845 on cover of No. 8, Moll., Pt. 3).—Cooper, Calif. State Mining Bureau, 7th Ann. Rept. State Mineralogist, p. 246, 1888. "San Diego well," Pliocene.

Glottidia albida Hinds, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 296, 1874. "Well at San Diego." "Pliocene." Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 94, 1903. "San Diego well (Hemphill)," Pliocene. Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 48, Dall's record of well at San Diego; p. 59, "excavations along India Street, particularly at the corner of Upas Street," 1944.—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 12, pl. 1, fig. 5 (San Diego, Recent), 6 (reproduction of original figure), 7 (Redondo Beach, Calif., Recent), text figs. 1a-1c (Recent), 1944. Page 14, "San Diego well"; "India and Upas streets"; "Soledad Mountain," Pliocene. Also cited from other localities in and near San Diego.

TYPE SPECIMEN[42]: [?] No. ZB.1, Department of Paleontology, British Museum (Natural History).

TYPE LOCALITY: "Bay of Magdalena, [Lower] California. In seven fathoms, among sandy mud."

RANGE: ?Late Eocene to Recent. Recent from Monterey Bay, California, to Acapulco Bay, Mexico, from the intertidal zone to 110 meters (60 fathoms) or perhaps to 146 meters (80 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego well, Balboa Park (Dall; Cooper; Arnold; Hertlein and Grant). CALIFORNIA ACADEMY OF SCIENCES: Loc. 957, upper beds of Pliocene section, 5 to 15 feet beneath overlying Pleistocene at Pacific Beach; Loc. 1181, gulch on south slope of Soledad Mountain about 1/3 mile west of Rose Canyon; Loc. 1399, in

(41) Morse, E. S., "Observations on Living Brachiopods," Mem. Boston Soc. Nat. Hist., Vol. 5, No. 8, pp. 313-386, pls. 39-61, 1902 (see especially p. 317).

(42) Dr. Helen M. Muir-Wood of the British Museum (Natural History), Department of Paleontology, furnished us the following information pertaining to the type specimen of this species. "The type specimen of *Glottidia albida* (Hinds) is more difficult since there is nothing in the 'Voyage of the Sulphur' Report to indicate where the figured specimen is located. Hinds mentioned that he had used the Cuming collection specimens in preparing his report and it seems probable that the Cuming specimen which was figured by Reeve, Conch. Icon. vol. 13, Mon. *Lingula,* 1862, plate 1, fig. 4, may be the same as Hinds' specimen. The pedicle in this specimen is no longer preserved and the two valves have been separated at some earlier date and attached in a rather broken condition to cardboard. Cuming's specimen corresponds quite well in size with Hinds' figure. There is no label with this specimen to show whether it was used by Hinds or not. The number of this specimen preserved in the Department of Paleontology is ZB.1."

bluff 100 to 200 yards south of Eocene-Pliocene contact at Pacific Beach; Loc. 1401, first canyon west of Rose Canyon on south slope of Soledad Mountain; Loc. 28880, road cut 0.1 mile east of Euclid Avenue on north side of Market Street, in Las Chollas Valley, San Diego; Loc. 28893, corner of India and Upas streets, San Diego. LOS ANGELES COUNTY MUSEUM: About 50 feet northeast from north end of quarry at Loc. 107 [=clay quarry at end of Arroyo Drive]; Loc. 305, 2400 feet east and 1350 feet south of northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). SAN DIEGO SOCIETY OF NATURAL HISTORY: Loc. 5, south slope of Soledad Mountain, same locality as Loc. 1181 (CAS); Loc. 34, northeast corner of India and Thorn streets, San Diego; Loc. 80, south slope of Soledad Mountain, same locality as Loc. 1181 (CAS); Loc. 417, fifth ravine north of Mexican boundary, about ¼ mile north of boundary, at west face of terrace about ¾ mile east of coast. UNIVERSITY OF CALIFORNIA AT LOS ANGELES: Loc. 296, street cut on northwest side of Fairmount Avenue, 0.4 mile north of intersection with Broadway, San Diego [=Loc. 400 (SD)]; Loc. 302 [=Loc. 28880 (CAS); Loc. 408 (SD)]; Loc. 309, oyster bed in building excavation at southeast corner of India and Upas streets, San Diego [=Loc. 415 (SD)]; Loc. 312, second ravine north of Loc. 294 (UCLA), and fifth ravine north of Mexican boundary, about ¾ mile east of coast, ravine debouching near north end of willow patch [=Loc. 417 (SD)]; Loc. 2359, south slope of Soledad Mountain, in soft fine-grained sandstone outcropping in small canyon parallel to and about 0.2 mile west of mouth of Rose Canyon and 0.4 mile north of Garnet Avenue. This locality is 2.6 miles S.40°E. of triangulation station on Soledad Mountain.

ORIGINAL DESCRIPTION: Testâ oblongâ, laevi, complanatâ, anticè truncatâ, ubiquè albidâ; pediculo brevi, cylindraceo. (Hinds.)

REMARKS: *Glottidia albida* is easily recognized by its elongate boat-shaped form and thin, smooth, shiny, yellowish or cream-colored shell. Recent specimens are sometimes ornamented with brown streaks along the sides of the shell.

Specimens of this small brachiopod, often about 15 to 20 mm. in length, occur at many localities in the San Diego formation. Perfect specimens, however, are not easily recovered because of the fragile nature of the shell. Excellent specimens, the largest approximately 20 mm. in length and 9.5 mm. in width, were collected by J. F. Arndt about 50 feet northeast of Loc. 107 (LAM).

The shell is less pointed posteriorly and the internal laminae are more divergent in this species than in *Glottidia palmeri* Dall[43], which occurs in the Gulf of California. The shell of *Glottidia audebarti* Broderip[44] also is more pointed posteriorly than that of *G. albida*, and in Recent specimens the distal half is colored bright green. Juvenile specimens of *Glottidia albida* are somewhat similar to those of *Glottidia semen* Broderip[45]. Judging from the description and illustrations, it appears that the shell of *G. semen* is smaller and thicker and the anterior end is straighter in outline.

Specimens from well cores from Pliocene strata in San Joaquin County, California, have been referred by us to the present species. Some of these have the posterior end somewhat more pointed than that of typical *Glottidia albida*, but this may be due to imperfect preservation. An imperfect specimen from a well core from the lower portion of the Kreyenhagen formation of late Eocene age in Fresno County, California, was questionably referred to *G. albida* by the present authors, but perfect specimens from beds of that age may show differences from Recent specimens.

Woodring[46] mentioned the rare occurrence of "*Glottidia* cf. *G. albida* (Hinds)" in the Cebada member of the Careaga sandstone in the Santa Maria district in southern California. Many species in the associated fauna also occur with *Glottidia albida* in the Pliocene beds at San Diego.

Glottidia albida is an inhabitant of fine sand and mud bottoms, where it affixes itself by its pedicle. It appears to be somewhat tolerant of salinity, and it usually does not occur in coarse sand or in the densest muds. It has been recorded as occurring from intertidal flats to a depth of 110 meters (60 fathoms) and perhaps 146 meters (80 fathoms). Mattox (1955) recorded it from depths of 15, 27, and 82 meters (8, 15, and 45 fathoms) on sandy bottoms around Santa Catalina Island, California.

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(43) *Glottidia* (*?albida* var.) *palmeri* Dall, Amer. Jour. Conch., Vol. 7, Pt. 2, p. 77, November 2, 1871. "Habitat at the head of the Gulf of California on the Lower California side, opposite the mouth of the Colorado River; in sandy shelly mud at low water mark."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 17, pl. 1, fig. 10, text fig. 2, 1944. Earlier records cited. Gulf of California.

(44) *Lingula audebardii* Broderip, Proc. Zool. Soc. London for 1833, p. 125, March 12, 1834. "Hab. ad Insulam Punam. (Bay of Guayaquil)." "Mr. Cuming found this species, at about half-tide, in an extensive bottom of hard coarse sand, from four to six inches below its surface."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 16, pl. 1, figs. 2-4, 1944. Earlier records cited. Lower California to Peru (as *Glottidia audebarti*).

(45) *Lingula semen* Broderip, Proc. Zool. Soc. London for 1833, p. 125, March 12, 1834. "Hab. ad Insulam Platam Columbiae Occidentalis." "Dredged by Mr. Cuming in fine coral sand from a depth of seventeen fathoms."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 20, pl. 1, fig. 1, 1944 (as *Glottidia semen*). Earlier records cited.

(46) Woodring, W. P., in Woodring, W.P., and Bramlette, M. N., "Geology and Paleontology of the Santa Maria District California," U.S. Geol. Surv., Prof. Paper 222, pp. 48 (insert), 62, 1951.

He mentioned that it did not occur commonly, but he suggested that it may occur in colonies because one bottom sample from 82 meters (45 fathoms) contained 43 individuals in an area of two square feet.

Class **ARTICULATA** Huxley

Order **TELOTREMATA** Beecher

Superfamily **TEREBRATULACEA** Waagen[47]

Family **TEREBRATELLIDAE** King

Terebratulacea in which the lophophore up to the schizolophus stage has the cirri directed inwardly. The primary invagination of the lophophore in the schizolophus stage is occupied by a median septum. The loop in the higher genera develops both from the cardinalia and the median septum, but may ultimately free itself from the latter, and the septum may be partly or wholly resorbed. (Thompson, 1927.) Jurassic to Recent.

Elliott[48] recently discussed the geological distribution and the origin of the Terebratelloid Brachiopoda.

KEY TO THE GENERA OF TEREBRATELLIDAE

A. Generally wider than long; sulcate; generally multiplicate or smooth; foramen large ..... *Terebratalia*

B. Generally longer than wide; anterior margin straight or with a slight sulcus; smooth, coarsely punctate; foramen small ..... *Laqueus*

Genus **TEREBRATALIA** Beecher

Terebratalia Beecher, Trans. Connecticut Acad. Arts and Sci., Vol. 9, Pt. 2, p. 377, 1893. "Type. *Terebratula transversa* G. B. Sowerby." —Thomson, New Zealand Board Sci. and Art, Manual No. 7, p. 245, 1927. "Genotype. —*Terebratula transversa* Sowerby." —Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, p. 275, 1940. "Genotype:—*Terebratula transversa* Sowerby." —Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 117, 1944. "Type of the genus (by original designation). —*Terebratula transversa* Sowerby."

TYPE SPECIES (by original designation): *Terebratula transversa* G. B. Sowerby [Proc. Zool. Soc. London for 1846, p. 94. No locality cited. —Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 135, pl. 8, figs. 10, 15, 16; pl. 9, figs. 1, 2, 5-7; pl. 21, figs. 8, 9, 1944 (as *Terebratalia transversa*). Earlier records cited, Miocene to Recent. Recent from the Shumagin Islands, Alaska, to Ensenada, Lower California, Mexico.]

RANGE: Oligocene to Recent from Japan to Lower California, Mexico. Recent in splash pools above high tide and at depths of 1463 meters (800 fathoms), but most of the species live at depths less than 183 meters (100 fathoms).

DESCRIPTION: Shell large, generally wider than long, sulcate, test smooth or more generally multiplicate. Beak short, suberect, beak-ridges sharp, with planareas on each side, foramen large, mesothyrid, attrite and generally much worn, incomplete or occasionally complete. Hinge-teeth supported by dental plates, which are small, recessive ventrally, and sometimes almost obsolete, pedicle-collar short, sessile. Cardinalia strong, somewhat variable, characterized by a callous deposit between the socket-ridges in the umbonal region, with which the septum unites; the crural bases are closely applied to the socket-ridges in the type species, and run back to join the callous deposit, but in other species are separated from the socket-ridges by partially excavate external hinge-plates, or may be much swollen. Cardinal process variable in size, fused with the callous deposit. Septum generally stout, but very low posteriorly. Loop generally with a narrow ribbon, long, reflected, and united to the septum by a narrow connecting

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[47] Cited as "Superfamily 2. Terebratulacea Waagen" by Schuchert in Eastman's edit. of Zittel's Text-Book of Palaeo., Vol. 1, p. 325, 1896. Waagen (Palaeo. Indica, Ser. 13, Vol. 1, Pt. 4, Fasc. 2, p. 447, 1883) proposed the "Sub-Order: Kampylopegmata, sive Terebratulacea, comprising the families: *Terebratulidae, Thecideidae, Rynchonellidae, and Stringocephalidae.*" There is also "Fam. 2. Terebratulacea" of Menke, 1830.

[48] Elliott, G. F., "On the Geographical Distribution of Terebratelloid Brachiopods," Ann. and Mag. Nat. Hist., Ser. 12, Vol. 4, No. 40, pp. 305-334, figs. 1-5, 1951; "The origin of the Terebratellacea (Brachiopoda)," Ann. and Mag. Nat. Hist., Ser. 12, Vol. 10, No. 112, pp. 259-264, April, 1957.

band from the descending branches. The pedicle is short, and the foraminal edges and sometimes the dorsal umbo are generally much abraded. (Thomson, 1927.)

REMARKS: Thirteen species and subspecies of this genus were cited in our earlier paper (1944) as occurring in the Cenozoic of the northeast Pacific. Hatai (1940) cited ten species from the Cenozoic of Japan.

KEY TO THE SPECIES OF TEREBRATALIA

A. Mesial flexure on the pedicle valve concave, on the brachial valve convex
  a. Mesial flexure usually pronounced; ribs about 9 on typical form (occasionally as many as 24) ..... *occidentalis*
  aa. Mesial flexure usually very weak; ribs about 40 on typical form ..... *arnoldi*
B. Mesial flexure on the pedicle valve convex, on the brachial valve concave ..... *hemphilli*

Terebratalia arnoldi Hertlein and Grant

Plate 19, Figure 30

Terebratalia smithi Arnold, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 170, 1912. "San Diego-Purisima." —J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego," Pliocene. —Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 133, 1944. "Pacific Beach, San Diego, between 100 and 200 meters south of the Eocene-Pliocene contact." Record by J. P. Smith also cited.

Not *Terebratalia smithi* Arnold, 1903.

Terebratalia arnoldi Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 119, pl. 11, figs. 1-3, 10-15, November 4, 1944.

TYPE SPECIMEN: No. 7313, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "From Loc. 27185 (Calif. Acad. Sci.), center of SW. 1/4 of Sec. 23, T.3N., R.18W., S.B.B. & M., Ventura County, California (C. Leach, collector, December, 1931). Middle Pliocene."

RANGE: Middle Pliocene in California.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1399, in bluffs 100 to 200 yards south of Eocene-Pliocene contact at Pacific Beach. LOS ANGELES COUNTY MUSEUM: Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach.

ORIGINAL DESCRIPTION: Shell resembling *Terebratalia occidentalis* Dall in general shape and ornamentation, but differing in having only a very slight development of a medial sulcus on the pedicle valve and fold on the brachial valve. The ribs increase by bifurcation and intercalation. Along the ventral margin of the pedicle valve of the type there are about forty ribs, but these are less in number on small specimens. Dimensions (of holotype): length, 41 mm.; width, approximately 42.3 mm.; convexity (of both valves), 22.4 mm. (Hertlein and Grant.)

REMARKS: A pedicle valve from the lower portion of the series of strata at Pacific Beach, comparable to *Terebratalia arnoldi,* measures 41 mm. in length, 39.3 mm. in width. The mesial basal portion of the valve is lacking, but on the remaining portion no trace of a mesial fold or sulcus is visible. The ratio of width to length is a little less than in typical specimens of *T. arnoldi,* but this specimen is quite similar to some of those of *T. arnoldi* from Pliocene beds in Tapo Canyon, Ventura County, California. Radial ribbing is present although imperfectly preserved on the present specimen. The lack of a mesial fold in this pedicle valve leads us to refer it to *T. arnoldi* rather than to *T. smithi* as was done in our earlier paper, 1944. Two eroded valves, the larger one 23.5 mm. in height, from Loc. 308 (LAM), are questionably referable to *T. arnoldi.*

Terebratalia smithi Arnold was described from strata on Deadman Island, San Pedro, California, originally believed to be of Pliocene age but now considered by some as Pleistocene. That species has a well-deveolped medial fold on the pedicle valve and sulcus on the brachial valve. It apparently is closely related to *Terebratalia hemphilli* and *T. transversa.* It has been recorded from several localities in beds of Pliocene age, but some of these occurrences may be referable to other species.

J. P. Smith reported *Terebratalia smithi* from the Pliocene beds at San Diego, but in collections from San Diego we have not seen any specimens certainly referable to that species. We are therefore inclined to refer Smith's record to *T. arnoldi,* although there is a possibility that it could refer to *T. hemphilli.*

Terebratalia arnoldi etchegoini Hertlein and Grant[49], described from the Etchegoin formation, of late Pliocene age, in the Coalinga district in the San Joaquin Valley, California, differs from the typical form in its smaller size, its often finer ribs, and its extremely variable and often distorted shape. This subspecies was reported recently [50] from Sonoma County, California, in beds of late Pliocene age probably equivalent to those of the lower portion of the Merced formation at its type locality.

An incomplete valve (UCLA coll.), collected by E. H. Quayle near the corner of India and Upas streets, San Diego, bears a faint medial sulcus similar to that of the *Terebratalia arnoldi* group. The preservation does not warrant a definite record, but, as mentioned in our earlier paper, the general appearance is suggestive of the subspecies *etchegoini.*

Terebratalia arnoldi quaylei Hertlein and Grant[51], described from the Santa Margarita formation, late Miocene, of San Luis Obispo County, California, differs from typical *T. arnoldi* in the decided development of a medial sulcus on the pedicle valve.

Some species described from beds of late Miocene and of Pliocene age in Japan[52] bear a strong resemblance to *Terebratalia arnoldi,* but their identity with the California form is not certain.

Terebratalia hemphilli Dall

Plate 19, Figures 26, 27

Terebratalia hemphilli Dall, Proc. U.S. Nat. Mus., Vol. 24, No. 1264, p. 561, pl. 40, figs. 8, 10, March 31, 1902.—J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego," Pliocene.—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 123, pl. 9, figs. 3, 4 (copies of original figures); pl. 10, figs. 1, 2 (from Tapo Canyon, Ventura County, Pliocene), 1944. P. 124 "Market and Euclid streets, San Diego" and "Pacific Beach." Pliocene.

Terebratalia hemphillii Dall, Carson, Pan-Amer. Geol., Vol. 43, No. 4, p. 268, May, 1925. "San Diego fauna," Pliocene.

TYPE SPECIMEN: No. 108,495, United States National Museum.

TYPE LOCALITY: "Pliocene of Santa Barbara, between one-half and 1 mile inland from the sea, in Arroyo Buero on the Hope ranch; collected by J. Howard Wilson. U.S.N.M., 108,495."

RANGE: Middle Pliocene to late Pliocene or early Pleistocene in southern California.

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego, unlocalized (J. P. Smith; Carson). CALIFORNIA ACADEMY OF SCIENCES: Loc. 547, Pacific Beach; Loc. 28880, road cut 0.1 mile east of Euclid Avenue on Market Street, in Las Chollas Valley, San Diego. LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach (juvenile specimens); Loc. 311, embankment on Windsor Drive where Tourmaline Street would intersect if projected, Pacific Beach district [= Loc. 28884 (CAS)].

ORIGINAL DESCRIPTION: Shell substantially as figured, thin, rather compressed or not very convex; transverse, valves with low, flattish, ill-defined radial riblets, which, except near the beaks, become obsolete toward the middle of the valves. Mesial flexure shallow, broad mesially concave. Area narrow, ill-defined; foramen narrow, high, incomplete below; punctation fine and profuse. Alt. 30.0, lat. 33.0, diam. 12.0 mm. (Dall.)

REMARKS: *Terebratalia hemphilli* resembles *T. smithi* Arnold[53] in general characters but differs in that the mesial portions of the valves are usually smooth, only the lateral areas being radially sculptured; also the shell is usually broader and the foramen smaller. The present species also is similar to large smooth forms of *Terebratalia transversa* Sowerby, but it is generally larger and broader in

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(49) *Terebratalia arnoldi etchegoini* Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 122, pl. 10, figs. 5, 9-11, November 4, 1944. "From Loc. 189 (Southern Pacific Coll., Calif. Acad. Sci.), 600 feet southeast of northwest corner of Sec. 26, T.22S., R.16E., M.D.B. & M., in base of conglomerate above blue sandstone, Coalinga district, California; Etchegoin, Pliocene."

(50) Peck, J. H., Jr., Program of Geol. Soc. America Cordilleran Sec. Fifty-third meeting at Univ. Calif. at Los Angeles, April 19-20, 1957, p. 31; Bull. Geol. Soc. America, Vol. 68, No. 12, Pt. 2, p. 1841, 1957.

(51) *Terebratalia arnoldi quaylei* Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 122, pl. 17, figs. 1, 4, 7, November 4, 1944. "Loc. 1106 (Univ. Calif. at Los Angeles), three miles southwesterly on the south side and up the Nacimiento River from the Nacimiento Ranch house, well towards the head of a ravine northwest of 1,108-foot hill, in the NW ¼ of the SE ¼ of Sec. 13, T.25S., R.10E., M.D.B. & M., Bradley Quadrangle, San Luis Obispo County, California (Mr. and Mrs. E. H. Quayle, collectors, March, 1938). Santa Margarita formation, upper Miocene. Associated with *Pecten (Lyropecten) estrellanus* Conrad."

(52) See *Dallinella smithi* Arnold, Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, p. 299, pl. 8, figs. 39, 40, 1940. Earlier records cited, "Miocene to Pliocene."

(53) *Terebratalia smithi* Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 93, pl. 17, fig. 9, 1903. "Pliocene of Deadman Island," San Pedro, California.—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 133, pl. 10, figs. 4, 6-8, 1944. Earlier records cited. Pliocene of central and southern California.

outline. An unusually large specimen in the collection at Stanford University measures 64 mm. in length, 58 mm. in width, and approximately 40 mm. in convexity. There is considerable variation in the degree of convexity or concavity as well as in the sculpture of the valves of this species.

A specimen from Loc. 28880 (CAS), on Market Street east of Euclid Avenue, San Diego, is referable to *Terebratalia hemphilli*. A single incomplete, almost smooth brachial valve (pl. 19, fig. 27), collected by Henry Hemphill from Pliocene beds at Pacific Beach appears to be referable to this species, but it could equally well be referable to *Terebratalia transversa* Sowerby. A well-preserved and only slightly imperfect pedicle valve (pl. 19, fig. 26), from Loc. 122 (LAM), Pacific Beach, bears fine radial riblets over the entire outer surface. It is 38.9 mm. in length, 38 mm. in width, and approximately 13.4 mm. in convexity (one valve). Two juvenile specimens, apparently referable to *T. hemphilli*, were collected by G. P. Kanakoff at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach.

Specimens typical of this species in the collections of the University of California at Los Angeles from Browns Canyon in the Newhall Quadrangle, Los Angeles County, are associated with typical Pliocene mollusks that also occur in the Pliocene beds at San Diego, including *Ostrea vespertina* Conrad, *Pecten bellus* Conrad, *Pecten healeyi* Arnold, and *Pecten opuntia* Dall.

Terebratalia occidentalis Dall

Plate 19, Figures 16, 22, 31

Terebratella occidentalis Dall, Proc. Calif. Acad. Sci., Vol. 4, Pt. 4, p. 182, pl. 1, fig. 7, January, 1872.

Terebratalia occidentalis Dall, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 170, 181, 1912. "San Diego-Purisima," Pliocene.—Gale in Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 46, 1931 [on pp. 30, 40 as *Terebratalia* (or *Dallinella*) *occidentalis*]. "San Diego formation."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 127, pl. 10, fig. 3 ("Pacific Beach, San Diego, California, Pliocene"); pl. 17, figs. 2, 5, 8, 11, 12, and text fig. 27 (all Recent), 1944. "Rare in lower 100-200 meters, and in the middle beds of the Pliocene at Pacific Beach, San Diego, California; northeast corner of India and Thorn streets, San Diego, California."

TYPE SPECIMEN: Originally No. 6 in the collection of the California State Survey. A specimen, No. 32180 in the type collection of the University of California, Invertebrate Paleontology, is said possibly to be the type specimen of this species. It is from Loc. 2390, ?Santa Barbara, California, a locality not cited by Dall at the time the species was described.

TYPE LOCALITY: "Habitat, coast of California. Monterey, Cooper and Dall. Catalina Island, Cooper. Cab. Cala. Geol. Survey No. 6."

RANGE: Oligocene to Recent. Recent from Anacapa Island[54], California (Dall), to Cape San Lucas, Lower California, Mexico, in 55 to 137 meters (30 to 75 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1399, rare in bluffs 100 to 200 yards south of Eocene-Pliocene contact at Pacific Beach; Loc. 1414, beds in middle portion of Pliocene section at Pacific Beach; Loc. 1419, northeast corner of India and Thorn streets, San Diego; Loc. 12007, Pacific Beach; Loc. 28158, Pacific Beach (L. M. Wright, coll.). LOS ANGELES COUNTY MUSEUM: "Old Town," north of Five Points, San Diego (J. F. Arndt, coll.).

ORIGINAL DESCRIPTION: Shell, variable in size and shade of color, usually of a flesh tint, deeper on some of the lines of growth. Sculptured by radiating ribs variable in number (9 in the typical specimen), with rather smooth interspaces, only crossed by more or less prominent lines of growth. Hinge line long, somewhat arched in the middle; area wide, sharply carinated, flat, crossed by transverse lines of growth. Apex not prominent, usually eroded. Foramen large, incomplete, deltidia widely separated and differentiated from the area by deep grooves. Typical specimen .75 in. long, .6 in. wide and .2 thick. (Dall.)

REMARKS: Most of the specimens of this species that we have seen from Pliocene beds at San Diego are single valves about 28 to 30 mm. in width. They are similar to Recent specimens of *Terebratalia occidentalis*.

The shell of this species varies considerably in sculpture; but it and members of its group are readily distinguished from other west American species of *Terebratalia* by the character of the mesial

(54) This species was recorded as occurring at San Francisco, California, by Cooper and at Monterey by Cooper and Dall. We have not seen specimens of this species from San Francisco. Concerning records of its occurrence at Monterey, California, Smith and Gordon (Proc. Calif. Acad. Sci., Ser. 4, Vol. 26, No. 8, p. 210, 1948) stated, "These are old records that have not been confirmed by recent collecting."

flexure, which is concave on the pedicle valve and convex on the brachial valve. Typical forms of this species are sculptured with about 9 radial ribs, but occasional specimens may have as many as 24 ribs. Some specimens are almost or entirely smooth, the smooth form being the subspecies *obsoleta* Dall[55]. There is complete intergradation between this form and typical *T. occidentalis;* but, although it may not have great taxonomic significance, it can be retained for convenience. Fossil specimens of *T. occidentalis* and its subspecies *obsoleta* attain a width of 45 mm. So far as known, Recent specimens are smaller.

The mesial flexure on specimens of *Terebratalia occidentalis* from the Oligocene and early Miocene is often rather subdued, and since this same tendency is noticeable on early members of *T. transversa* Sowerby, it appears possible that the two groups, *T. occidentalis* and *T. transversa,* may have diverged from a common stock at about this time.

Several related forms belong to the *Terebratalia occidentalis* group. These include *T. occidentalis,* Oligocene to Recent, *T. occidentalis obsoleta* Dall, Miocene to Recent, *T. arnoldi* Hertlein and Grant, early and middle Pliocene, *T. arnoldi quaylei* Hertlein and Grant, late Miocene, *T. arnoldi etchegoini* Hertlein and Grant, late Pliocene, and *T. jordani,* Pliocene (in the Gulf of California region). All these have been discussed and illustrated in our earlier paper, 1944. Woodring[56] and Mattox have questioned the distinctness of *T. arnoldi* from *T. occidentalis,* but an examination of a series of fossil and Recent specimens leads us, at least for the present, to retain *T. arnoldi* as a separate species.

Most of the records of the Recent occurrences of *Terebratalia occidentalis* are from depths not exceeding 91 meters (50 fathoms). According to Mattox it is the second most abundant brachiopod in the waters about Santa Catalina Island, southern California, where it occurs singly or in small clusters, in the ratio of about one to 100 specimens of *Laqueus californianus* Koch.

Genus **LAQUEUS** Dall

Laqueus Dall, Amer. Jour. Conch., Vol. 6, Pt. 2, p. 123, pl. 7, fig. f; pl. 8, figs. 9, 10, October 6, 1870. "Type. *Laqueus californicus,* Koch sp."—Thomson, New Zealand Board Sci. and Art, Manual No. 7, p. 258, fig. 85 (a, b, c), 1927. "Genotype. *Terebratula californica* Koch."—Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2, (Geol.), Vol. 20, p. 343, 1940. "Genotype.—*Terebratula californica* Koch."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 143, 1944. "Type of the genus (by original designation).—*Laqueus californicus* Koch [=*Terebratula californiana* Koch]."

TYPE SPECIES (by original designation): *Laqueus californicus* Koch [=*Terebratula californiana* Koch].

RANGE: Miocene to Recent, from Japan to Lower California, Mexico. Recent off western North America in from 4 to 252 meters (2 to 138 fathoms), usually in less than 182 meters (100 fathoms). Fragment reported by Dall from a depth of 1575 meters (861 fathoms).

DESCRIPTION: Shell large, ovate, hinge-line curved, biconvex rectimarginate to ligate or strangulate, test smooth, rather coarsely punctate, colour yellow-brown to red, sometimes with bright-red rays. Beak fairly prominent, beak-ridges sharp, foramen small to moderate, permesothyrid, slightly remigrant, telate, deltidial plates conjunct, concave. Hinge-teeth supported by dental plates, which are ventrally recessive; area between dental plates slightly calloused, pedicle-collar (or a striated area) sessile, long, but not reaching as far forward as the dental plates. Cardinalia characterized by inner and outer hinge-plates separated by the crural bases, as in *Dallina,* the inner hinge-plates resting on the median septum; no cardinal process, but a small striated area or pit over the umbo. Septum extending forward more than one-third the length of the valve. Loop long, reflected, attached to the septum by connecting bands as in *Terebratalia,* the ascending branches united to the descending branches by the interconnecting bands on each side in the neighborhood of the connecting bands. Muscular impressions not strong. Small spicules present over the pallial sinuses, but not extending to the body-wall or lophophore. (Thomson, 1927.)

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(55) *Terebratalia occidentalis* var. *obsoleta* Dall, Proc. U.S. Nat. Mus., Vol. 14, No. 849, p. 186, July 24, 1891. "*Albatross,* station 2984, in 113 fathoms, off Cerros Island, Lower California."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 131, fig. 28, pl. 12, figs. 5, 9-11, 1944 (as *Terebratalia occidentalis obsoleta*). Earlier records cited, Miocene to Recent.

(56) Woodring, W. P., in Woodring, W. P., and Bramlette, M. N., "Geology and Paleontology of the Santa Maria District," U.S. Geol. Surv., Prof. Paper 222, p. 68, 1950.

REMARKS: *Laqueus* is confined to the margins of the north and northeastern Pacific. It is known to occur from Pliocene to Recent in California and from Miocene to Recent in Oregon, Washington, Alaska, and Japan. Species of this genus usually occur at moderate depths on clear sea bottoms free of mud, and a greater number occur in warm rather than cold waters.

Fourteen species were cited by Hatai as occurring in the late Cenozoic of Japan. Two species occur at the present time in waters of the northeastern Pacific region.

KEY TO THE SPECIES OF LAQUEUS

A. Shell thin; pedicle opening small; length usually exceeding 40 mm.....*californianus*

B. Shell thick; pedicle opening large; length usually not exceeding 35-40 mm.....*vancouveriensis diegensis*

Laqueus californianus Koch

Plate 20, Figures 1-3, 5-7

Terebratula californiana Koch in Küster, Martini-Chemnitz Conchyl.—Cab. (ed. by Küster and Kobelt), Bd. 7, Abt. 1, *Terebratula*, p. 38, 1848, pl. 2b, figs. 21-23; 1844.

Laqueus californianus Koch, Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 144, pl. 13, figs. 5, 8, 14; pl. 21, figs. 1-7; text fig. 31, 1944. Earlier records cited. ?Pliocene, California. Recent, British Columbia to Point Loma, California.—Mattox, Essays in Nat. Sci. in Honor of Captain Allan Hancock on the Occasion of his Birthday July 26, 1955 (Univ. South. Calif. Press), p. 75, fig. 2, November 8, 1955. Catalina Island, California, in 30 to 120 fathoms, Recent.

TYPE SPECIMEN: Location unknown to the present authors.

TYPE LOCALITY: "Aufenthalt: in Californien."

RANGE: Middle Pliocene, in southern California, to Recent. Recent from British Columbia to Point Loma, California, in 46 to 549 meters (25-300 fathoms); [?] (fragment) 1575 meters (861 fathoms) (Dall.)

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 107, 100-foot bluff with fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego.

ORIGINAL DESCRIPTION: T. testa maxima, ovata, ventricoso-convexa, robusta, cornea, opaca, concentrice striata et sulcata, marginibus integris, sinuatis; rostro obtuso, incurvo; area late trigono; foramine integro, parvo.

Muschel sehr gross, eiförmig, bauchig gewölbt, starkwandig und von kräftigem Bau, horngrau, fast glanzlos, mit feinen concentrischen Anwuchsstreifen und stärkeren Furchen, kleiner Schale fast flacher, gegen die Ränder etwas gedrückt, der Oberrand schief, gegen den Wirbel ansteigend, der Wirbel nagelförmig, fast anschliessend. Auf der Fläche beider Schalen zeigen sich mehrere grössere und kleinere Eindrücke, welche sich meist als Furchen bis an den Rand fortsetzen und dort mit denen der andern Schale zusammentreffen. Grössere Schale stärker gestreift, vorzüglich gegen den Unterrand, der Wirbel ist wenig erhöht, stark übergebogen, Schild breit, beiderseits durch eine fast kielförmige Erhöhung abgegränzt; Oeffnung sehr klein, rund. Höhe 27‴, Länge 21‴, Breite 15‴. (Koch.)

REMARKS: Several specimens collected by G. P. Kanakoff at Loc. 107 (LAM), end of Arroyo Drive, San Diego, are referable to *Laqueus californianus*. Some of these are somewhat deformed by compaction of the enclosing sediment, but the observable features are all characteristic of this species: the shell is thin and elongate, with a small pedicle opening. They are uniformly dark brown, probably in part because of iron stain. The largest specimen measures 41.8 mm. in length, 30 mm. in width, and 19.1 mm. in convexity (both valves together). A more rounded specimen measures 38 mm. in length, 33.5 mm. in width, and 18 mm. in convexity (both valves together).

Large specimens of the Recent form attain a length of at least 51.5 mm. Those occurring in shallow water are red, while those in deeper water, from 55 to 110 meters (30 to 60 fathoms), tend to be white. They often occur in colonies, some individuals attached to others. Mattox found one cluster of 31 individuals. Also he found occasional individuals attached to *Bursa californica* Hinds. He reported that in 55 to 219 meters (30 to 120 fathoms) off Catalina Island, *Laqueus californianus* is about 100 times as abundant as *Terebratalia occidentalis* Dall, with which it often occurs.

Records of this species in Pliocene strata are very few. Arnold[57] recorded *"Laqueus californicus (or jeffreysi)"* from Pliocene beds in Temescal Canyon in Los Angeles County, and Thomson (1927, p. 259) recorded it from "Pliocene, California."

Laqueus japonicus Yabe and Hatai[58] bears a resemblance to *L. californianus;* but it is said to differ in the thicker shell, the larger foramen, the more incurved beak, and the brownish coloration.

Under the name *"Laqueus californicus convexus",* Konjukova[58a] recently described a brachiopod with very convex valves and with a very large foramen, from Tatar Strait and the northern part of the Sea of Japan, in 57 to 215 meters. We have not seen specimens.

Laqueus vancouveriensis diegensis Hertlein and Grant, new subspecies

Plate 20, Figures 4, 8-21

Laqueus jeffreysi Dall, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 94, 1903. "Pliocene of Pacific Beach."—Arnold, U.S. Geol. Surv., Prof. Paper 47, p. 28, 1906. "San Diego formation as developed in the type section at Pacific Beach."

Not *Laqueus jeffreysi* Dall, 1895.

Laqueus californicus vancouveriensis Davidson, E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, pp. 416, 426, pl. 27, fig. 7 (Cedros Island, Pliocene), 1926. "Santa Barbara and San Diego Pliocene formations of southern California."—Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 82, 1929. "San Diego Pliocene."

Not *Laqueus californicus* var. *vancouveriensis* Davidson, 1887.

Laqueus vancouveriensis Davidson, Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 147, pl. 13, figs. 6, 7, 9, 10, 1944. "Pacific Beach, San Diego, California. Pliocene." (Not pl. 17, figs. 15-17; pl. 18, figs. 15-17, 19-21; text fig. 32 =*L. vancouveriensis* Davidson).

Not *Laqueus californicus* var. *vancouveriensis* Davidson, 1887.

TYPE SPECIMEN: No. 7355 (and Paratype No. 7354), Type Collection, Department of Geology, California Academy of Sciences. Paratypes, San Diego Society of Natural History and Los Angeles County Museum.

TYPE LOCALITY: Pacific Beach, San Diego, California; Pliocene; H. Hemphill, collector. Paratypes also from Pacific Beach.

RANGE: Middle Pliocene in southern California and at Cedros Island, Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego (Arnold; E. K. Jordan and Hertlein; Hertlein; Hertlein and Grant). CALIFORNIA ACADEMY OF SCIENCES: Locs. 104, 537, 12005, 12006, 31356, Pacific Beach; Loc. 28884, embankment on Windsor Drive where Tourmaline Street would intersect if projected. LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach; Loc. 311 [=Loc. 28884 (CAS)]; Loc. 311A, at base of recent road cut on Windsor Drive about 20 feet toward embankment from Loc. 311 (LAM); Loc. S8439, north end of Diamond Street (Charles Sternberg, Coll.). SAN DIEGO SOCIETY OF NATURAL HISTORY: Loc. 81, south slope of Soledad Mountain; Loc. 726, Pacific Beach; Loc. 5007 [=Loc. 28884 (CAS)]. UNIVERSITY OF CALIFORNIA AT LOS ANGELES: Loc. 593 [=Loc. 28884 (CAS) and Loc. 726 (SD)]; Loc. 2420, soft yellow Pliocene sands exposed in bluffs along Pacific Beach about ½ mile southeast of False Point at foot of Law Street.

DESCRIPTION: Shell with general characters of *Laqueus vancouveriensis* Davidson but differing in that the umbo of the pedicle valve is broader and has a larger pedicle opening, the posterior margin of the brachial valve is more broadly rounded, and the shell is larger and thicker. Dimensions: length 34.5 mm.; width 29.5 mm.; convexity (both valves together) 21.6 mm.

REMARKS: This form has been recorded from Pliocene beds in Lower California and in southern California[59], at least in some instances under the name of *Laqueus vancouveriensis* Davidson. That species now occurs from the Aleutian Islands, Alaska, to off Lopez Island, Puget Sound, Washington. Comparison of many fossil specimens from San Diego with Recent specimens shows differences which appear sufficient to justify the separation of the fossils as a subspecies.

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[57] Arnold, R., "The Tertiary and Quaternary Pectens of California," U.S. Geol. Surv., Prof. Paper 47, p. 77, 1906. See also U.S. Geol. Surv., Bull. 309, p. 153, 1907 (as *Laqueus californicus*? Koch).

[58] *Laqueus japonicus* Yabe and Hatai, Proc. Imper. Acad. Japan, Vol. 10, No. 10, p. 663, figs. 19-21, 26, December, 1934. "Type loc.: Sagami Bay?."—Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, p. 365, pl. 5, figs. 10-19, 23-25, 1940. Miocene or Pliocene to Recent, Japan.

[58a] Konjukova, E.D., Akad. nauk SSSR, Zool Inst., Issledovaniia Dal'nevostochnikh Morei SSSR (Moskva; Leningrad), Vol. 4, p. 53, figs. 37, 38, pl. 7, figs. 1-12, 1957.

[59] George Willett (Bull. South. Calif. Acad. Sci., Vol. 45, Pt. 1, January-April, p. 32, June 10, 1946) mentioned the occurrence of *Laqueus "vancouverensis"* Davidson in strata of Pliocene age at Fourth and Broadway streets in Los Angeles, California.

This fossil form differs from the species described by Davidson[60] in the gross shell characters mentioned above. The shell is decidedly thicker and attains a larger size. Dimensions of five of the largest specimens are as follows:

	Length	Width	Convexity
Holotype (CAS) from Pacific Beach	34.5 mm.	29.5 mm.	21.6 mm.
Paratype (CAS) from Pacific Beach	33.8 mm.	31.0 mm.	20.5 mm.
Paratype (SD) from Pacific Beach	30.6 mm.	24.0 mm.	20.8 mm.
Paratype (LAM) from Pacific Beach	36.4 mm.	28.0 mm.	23.0 mm.
Hypotype (CAS) from Cedros Island	37.9 mm.	33.8 mm.	23.0 mm.

The largest Recent specimen of *Laqueus vancouveriensis* which has come to our attention is 34.5 mm. in length. This is unusual: the average length is about 25.3 mm.

Both *Laqueus vancouveriensis* and the new subspecies described here differ from *Laqueus californianus* Koch in the smaller size, thicker shell, and larger pedicle opening. Recent specimens of *L. vancouveriensis* are drab or yellowish rather than pink or white as in *L. californianus*; and they usually occur singly or in small groups rather than in huge colonies.

This new subspecies occurs rather abundantly in the Pacific Beach district at Loc. 28884 (CAS), in the embankment on Windsor Drive where Tourmaline Street would intersect if projected, and at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street.

[60] *Laqueus californicus* var. *vancouveriensis* Davidson, Trans. Linn. Soc. London, Ser. 2, Zool., Vol. 4, Pt. 2, p. 113, pl. 18, figs. 10-13, 13a, 13b, July, 1887. "Off Vancouver Island." Also other localities cited. See Hertlein and Grant, 1944, p. 147, pl. 17, figs. 15-17; pl. 18, figs. 15-17, 19-21; text fig. 32.

Dr. Helen M. Muir-Wood informed us that syntypes of this form in the Department of Paleontology, British Museum (Natural History), illustrated by Davidson, bear the following numbers: plate 18, fig. 10 = ZB. 1611; fig. 11 = ZB. 1610; fig. 12 = ZB.1 2459; fig. 13 = ZB. 1609.

Phylum **ECHINODERMATA** Bruguière

Class **ASTEROIDEA** Burmeister

Order **PHANEROZONIA** Sladen

Family **ASTROPECTINIDAE** Gray

Back flattish, netted with numerous tubercles, crowned with radiating spines at the tip, called Paxilli. (Gray, 1840). Jurassic to Recent.

Genus **ASTROPECTEN** Linck in Gray

Astropecten Linck in Gray, Ann. and Mag. Nat. Hist., Vol. 6, No. 36, p. 180, November, 1840. Several species cited including "*Astropecten aurantiacus.* Asterias aurantiaca, *Linn.*" —Fisher, Smithson. Miscell. Coll., Vol. 52, No. 1799, p. 93, May 27, 1908. Type: *Astropecten aurantiacus* Linnaeus.—Fisher, U. S. Nat. Mus., Bull. 76, Pt. 1, p. 55, June 30, 1911. Type as indicated in 1908.

TYPE SPECIES (designated by Fisher, 1908, p. 93): "No type was designated by Gray; as it is desirable to have one, *A. aurantiacus*[61] (Linn.) may be so considered." [= *Asterias aranciaca* Linnaeus, Syst. Nat., ed. 10, p. 662, 1758. "Habitat in M. Mediterraneo." Ref. to "Link. Stell. t.4.f.14; t.5.f.6; t.8.f.12; t.23.f.38; t.27.f.44; t.36.f.63"; also others. Also illustrated by Ludwig, Fauna und Flora des Golfes von Neapel (Berlin), Monogr. 24, pp. 3-16, pl. 2, figs. 1, 2,; pl. 6, figs. 1-5; text fig. on p. 3, 1897 (as *Astropecten aurantiacus*). Mediterranean; Madeira; Bay of Setubal, Portugal; Canary Islands. Depth, 1-183 meters. — H. L. Clark in Eastman's ed. 2 of Zittel's Text-Book of Paleo., Vol. 1, p. 247, fig. 349, 1913. Recent, Mediterranean].

RANGE: Miocene to Recent (Hess). Cosmopolitan. Species assigned to this genus by Sladen, 1889, occur at depths of 4 to 823 meters (2 to 450 fathoms), but most of them occur at depths less than 91 meters (50 fathoms).

DESCRIPTION: Rays normally five in number; abactinal surface flat, not arched; actinal surface slightly beveled on sides; disk variable in size, usually medium to small; rays usually long and tapered; marginal plates large, the inferomarginals always broader than superomarginals and sometimes extending laterally beyond them; inferomarginals armed with spinelets and a variable number of spines which increase in size toward the edge of ray; superomarginals, in addition to small granules or spinelets, may also bear tubercles or enlarged spines extending in one or two complete or interrupted rows along ray; or enlarged spines may be entirely absent; exposed surface of consecutive marginal plates separated by deep fasciolar grooves lined by minute capillary spinelets, these grooves acting as percolators or filters; abactinal area covered with true paxillae; papulae single, usually absent from a narower or wider midradial line, and from center of disk; usually six about each paxilla; actinal interradial areas typically very small, with few paxilliform intermediate plates which do not extend far along ray, the inferomarginals and adambulacrals being in contact on the ray proper; intermediate plates never extend beyond middle of ray and rarely beyond proximal fourth; ambulacral plates with an angular furrow margin, bearing typically three spines, of which the middle is slightly the longer; two or three rows of spines on actinal surface of plates; first adambulacral plate compressed, much wider than the rest; mouth plates narrow, the inner spines enlarged; tube feet conical, without a true sucking disk; no true pedicillariae; anus typically absent; gonads interradial, not extending along ray; superambulacral plates well developed. (Fisher, 1911.)

REMARKS: *Astropecten* differs from *Tritonaster* Fisher in the character of the superomarginal plates, which are not conspicuously smaller beyond the middle of the ray, and in the presence of well-developed marginal fascioles.

Fisher (1908) discussed the problems concerning the nomenclature of this genus. He pointed out that *Astropecten* of Linck, 1733, is pre-Linnaean, that *Astropecten* of Schultz, 1760, is non-binomial,

(61) The specific name *aranciaca* Linnaeus was emended to *aurantiaca* by Tiedemann, 1816. See H. L. Clark, Carnegie Inst. Washington, Publ. 566, p. 72, 1946.

and hence that neither is available. He did not mention the usage of the genus name by Blainville[62], who accepted Linck's genus. For the present we accept Gray's usage of the genus name and leave any further nomenclatural questions concerning it to specialists in the Asteroidea.

Durham and Roberts[63] summarized the known occurrences of fossil asteroids in North America. They described *Astropecten matilijaensis* from beds of late Cretaceous age in Ventura County, California; but this species appears to belong in *Archastropecten,* where it was placed by Hess (1955, p. 44). Therefore, *Astropecten armatus,* from Pliocene beds in San Diego, is the only known fossil *Astropecten* in western North America.

Hess[64] reviewing the species of fossil Astropectinidae, transferred most of the previously described Mesozoic fossils from *Astropecten* to *Archastropecten* Hess. The type of this genus is *Astropecten huxleyi* Wright, 1862, from strata of late Jurassic age in England. According to Hess, the most important distinction between the two genera is the character of the flattened surfaces of the joints of the marginal plates. In *Archastropecten* these surfaces are large and simple and differ proximally and distally; consequently, they fit together very closely. In *Astropecten* these surfaces are smaller, more deeply excavated, and more differentiated.

Asterias rémondii Gabb[65] was described long ago from beds now referred to the San Pablo formation of late Miocene age in the San Francisco Bay district in California.

Astropecten armatus Gray

Plate 23, Figures 8, 9

Astropecten armatus Gray, Ann. and Mag. Nat. Hist., Vol. 6, No. 36, p. 181, November, 1840.—Fisher, U. S. Nat. Mus., Bull. 76, Pt. 1, p. 56, pl. 5, figs. 1-2; pl. 7, figs. 3,6; pl. 50, fig. 4; pl. 51, fig. 3, June 30, 1911. San Pedro, California, to Punta Santa Elena, Ecuador, Recent.—Ziesenhenne, Zoologica, New York Zool. Soc., Vol. 22, Pt. 3, p. 211, October 7, 1937. San Pedro, California, to Punta Santa Elena, Ecuador; Clarion Island; Recent.

TYPE SPECIMEN: No. 1938.5.12.27., British Museum (Natural History).

TYPE LOCALITY: "Inhab. Puerto Portrero, South America, on sandy bottoms, 9 fathoms. H. Cuming, Esq. Var. 2." [Costa Rica.]

RANGE: Middle Pliocene to Recent. Recent from San Pedro, California, to Punta Santa Elena, Ecuador; Clarion Island, Revillagigedo Islands, Mexico. Shore to 146 meters (80 fathoms), on muddy, sandy, and rocky bottoms. (Ziesenhenne.)

OCCURRENCE IN THE SAN DIEGO FORMATION: UNIVERSITY OF CALIFORNIA AT LOS ANGELES: Corner of Market Street and Euclid Avenue, San Diego.

ORIGINAL DESCRIPTION: Rays elongate, regularly tapering; upper marginal tubercles narrow, with a continued series of erect, elongated, subulate spines. Var. 2. *Pulcher,* the under series of marginal tubercles not produced, and the spines more slender. (Gray).

Diagnostic features of this species given by Fisher (1911, p. 60) follow:

"*Armatus* may be distinguished from the other two Californian astropectens by the presence of at least a few superomarginal spines or tubercles, by the broader and more tumid superomarginal plates, by the enlarged central granules of the paxillae, by the heavier and more bristling inferomarginal armature, and especially by the chisel-shaped enlarged adambulacral spine, which is broader at tip than at base, and usually more or less hollowed at the end, on the upper (or outer) side, like a gouge. Even young specimens of *armatus* have a few superomarginal tubercles, although these are usually inconspicuous. In lieu of the superomarginal spines the enlarged central granules of paxillae and the specialized adambulacral spine may be used to determine doubtful specimens." (Fisher, 1911.)

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(62) Blainville (Dict. Sci. Nat., Vol. 60, p. 220, 1830) cited "(*G. Astropecten,* Link; *Crenaster,* Luid.)", with 30 species, of which *A. aranciaca* is the first one.

(63) Durham, J. W., and Roberts, W. A., "Cretaceous Asteroids from California," Jour. Paleo., Vol. 22, No. 4, pp. 432-439, pls. 65, 66, July, 1948. Two new species were described by Durham and Roberts. These are *Astropecten matilijaensis* (p. 435, pl. 65, figs. 1-5; pl. 66, figs. 2, 4, 5) and *Henricia*(?) *venturana* (p. 437, pl. 66, figs. 1, 3), from "6.3 miles northeast along the road from Wheeler Springs, on the highway from Ojai to the Cuyama Valley. Referring to the 1942 reprint of the 1903 edition of the Mt. Pinos, Calif. Quadrangle . . . the locality appears to be in the SE¼ of the SE¼ of Sec. 2, T5N, R23W, Ventura County, California."

(64) Hess, H., "Die Fossilen Astropectiniden (Asteroidea). Neue Beobachtungen und Übersicht über die bekannten Arten," Schweiz. Palaeo. Abhandl., Bd. 71, No. 3, pp. 1-113, figs. 1-62, pls. 1-4, 1955.

(65) *Asterias rémondii* Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 37, pl. 13, fig. 69, February, 1866. "Found abundantly at 'Star Fish Point,' on the Pinole Ranch, south of the Straits of Carquinez, about five miles from Martiñez; Miocene."

REMARKS: A portion of a single ray, 13.8 mm. in length and 12 mm. in maximum width, with 8 plates in one series and 6 in the other, is in the collection of the University of California at Los Angeles. It was collected by B. H. Brattstrom at the corner of Market Street and Euclid Avenue, San Diego. This fragment is similar in observable characters to the corresponding portion of *Astropecten armatus* Gray, which at the present time occurs in the waters off San Diego. This conclusion was affirmed by Mr. Fred C. Ziesenhenne, who compared the fossil with a series of Recent specimens of *A. armatus* in the Allan Hancock Foundation. The fossil is therefore referred to the Recent species.

Class **ECHINOIDEA** Leske

A paper by the present authors published in 1938[66] contains many references to and discussions of west American Cenozoic Echinoidea. Since the submission of our monograph on west American Cenozoic Echinoidea, several important papers have appeared, including those of Ziesenhenne[67], A. H. Clark[68], H. L. Clark[69], Caso[70], and Durham[71], as well as the later portions of the great monograph by Mortensen[72].

Mayr[73] published an interesting paper dealing with speciation in tropical American echinoids. C. W. Cooke[74] is the author of two very useful papers dealing with the Cenozoic echinoids of the eastern United States. A recent paper by Durham and Melville[75] deals with the classification of echinoids.

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(66) Grant, U. S., IV, and Hertlein, L. G., "The West American Cenozoic Echinoidea," Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, pp. i-vi, 1-225, figs. 1-17, pls. 1-30, April 19, 1938.

(67) Ziesenhenne, F. C., "The Templeton Crocker Expedition. X. Echinoderms from the West Coast of Lower California, the Gulf of California and Clarion Island," Zoologica, New York Zool. Soc., Vol. 22, Pt. 3, pp. 209-239, figs. 1, 2, October 7, 1937.

(68) Clark, A. H., "Echinoderms from the Pearl Islands, Bay of Panamá, with a Revision of the Pacific Species of the Genus Encope," Smithson. Miscell. Coll., Vol. 106, No. 5, (Publ. 3849), pp. 1-11, pls. 1-4, July 18, 1946.

(69) Clark, H. L., "A Report on the Echini of the Warmer Eastern Pacific, Based on the Collections of the Velero III," Allan Hancock Pac. Exped., Vol. 8, No. 5, pp. 225-352, figs. 1-3, pls. 35-71, December 29, 1948. ("Hubert Lyman Clark: Teacher and Friend", by F. A. Chase, Jr., pp. ii-iv and portrait; "Bibliography of Dr. H. L. Clark's Echinoderm Papers," by Marjorie Pattee, pp. v-ix; "Preface", by Th. Mortensen, pp. xi-xii).

(70) Caso, M. E., "Contribucion al Conocimiento de los Equinoideos de Mexico," An. Inst. Biol. Mexico, Vol. 17, Nos. 1 & 2, pp. 247-259, figs. 1-10, 1946; also Vol. 19, No. 1, pp. 183-231, figs. 1-24, 1948; Vol. 20, Nos. 1 & 2, pp. 342-355, figs. 1-6, 1949. See also: "Los Equinoides Fósiles del Cenozoico de México," Bol. Assoc. Mex. Geol. Petrol., Vol. 3, Nos. 1-2, pp. 37-96, 1951; "El Genero Clypeaster Lamarck 1801, en el Terciario de Mexico," An. Inst. Biol. Univ. Mexico, Tom. 27, No. 2, pp. 487-528, figs. 1-23, 1 table, 1957.

(71) Durham, J. W., "Classification of Clypeasteroid Echinoids," Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, pp. i-v, 73-198, figs. 1-38, frontispiece and pls. 3-4, November 21, 1955.

(72) Mortensen, Th., "A Monograph of the Echinoidea."

I. Cidaroidea, text (pp. 1-551, 173 figs.), atlas (pp. 1-24, pls. 1-88), December 7, 1928.

II. Bothriocidaroida, Melonechinoida, Lepidocentroida, and Stirodonta, text (pp. 1-647, 377 figs.), atlas (pp. 1-16, pls. 1-89), February 22, 1935.

III.1. Aulodonta, text (pp. 1-370, 197 figs.), atlas (pp. 1-22, pls. 1-77), April 25, 1940.

III.2. Camarodonta. I, text (pp. 1-553, 321 figs.), atlas (pp. 1-23, pls. 1-56), February 22, 1943.

III.3. Camarodonta. II, text (pp. 1-446, 215 figs.), atlas (pp. 1-23, pls. 1-66), October 1, 1943.

IV.1. Holectypoida and Cassiduloida, pp. 1-371, pls. 1-14, 326 figs. in text, February 7, 1948.

IV.2. Clypeastroida, text (pp. 1-471, 258 figs.), atlas (pp. 1-20, pls. 1-72), December 30, 1948.

V.1. Spatangoida. I, pp. 1-432, pls. 1-25, 315 figs. in text, December 21, 1950.

V.2. Spatangoida. II, text (pp. 1-593, 286 figs.), atlas (pp. 1-30, pls. 1-64), December 20, 1951.

Index to Vols. I-V, pp. 1-62. Additional note, p. 63, December 20, 1951.

(73) Mayr, E., "Geographic Speciation in Tropical Echinoids," Evolution, Vol. 8, No. 1, pp. 1-18, figs. 1-7 (maps), March 31, 1954.

(74) Cooke, C. W., "Cenozoic Regular Echinoids of Eastern United States," Jour. Paleo., Vol. 15, No. 1, pp. 1-20, pls. 1-4, January, 1941; "Cenozoic Irregular Echinoids of Eastern United States," Jour. Paleo., Vol. 16, No. 1, pp. 1-62, pls. 1-8, January, 1942.

While the present paper was in press, there appeared another publication of C. W. Cooke: "Cenozoic Echinoids of Eastern United States", U. S. Geol. Surv., Prof. Paper 321, pp. i-iii, 1-106, pls. 1-43, 1959.

(75) Durham, J. W., and Melville, R. V., "A Classification of Echinoids," Jour. Paleo., Vol. 31, No. 1, pp. 242-272, figs. 1-9, January, 1957.

Order **CIDAROIDA** Claus

Family **CIDARIDAE** Gray

Test stout, with relatively few plates in each interambulacral column; each plate with one primary spine or none. Primary spines very large. Primary tubercles perforate. (H. L. Clark, 1925.) Jurassic to Recent.

KEY(76) TO THE GENERA OF CIDARIDAE

A. Primary spines coarse, ending in a small crown with a central prominence (more rarely tapering to a fine point); pores on peristome partly in double series (not in *E. metularia*) ..... *Eucidaris*

B. Primary spines slender, sometimes widened and flattened towards the end; pores on peristome in single series ..... *Hesperocidaris*

Genus **EUCIDARIS** Pomel

Eucidaris Pomel, Méth. et. Gén. Echin. Viv. Foss. [Paléo. Descript. Anim. Foss. de L'Algérie, Zooph. (Alger), Fasc. 2], p. 109, 1883.—Mortensen, Monogr. Echin. I. Cidaroidea, p. 384, 1928. "Genotype: *Cidarites metularia* Lamarck."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 7, 1938. "Type of the genus (designated by H. L. Clark, ... 1909): *Cidaris metularia* Lamarck."

TYPE SPECIES (designated by H. L. Clark, Ann. and Mag. Nat. Hist., Ser. 8, Vol. 3, p. 88, January, 1909): *Cidaris metularia* Lamarck [= *Cidarites metularia* Lamarck, Anim. s. Vert., Vol. 3, p. 56, 1816. "Habitate l'océan des Grandes-Indes, les Côtes de l'Ile-de-France, celles de Saint-Domingue." Illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), pt. 1, p. 98, 1872; Pt. 3, p. 385, pl. 1c, figs. 23, 23a, 23b, 24, 24a, 24b; pl. 1g, fig. 1; pl. 35, fig. 3, 1873 (as *Cidaris metularia*). "Red Sea; Mauritius; East India Islands; Sandwich Islands; Feejee Islands."—Mortensen, Monogr. Echin. I. Cidaroidea, p. 386, pl. 41, figs. 1-8; pl. 73, fig. 6; pl. 86, figs. 11-14, text figs. 113a, 113b, 114, 115 (1), 116, 1928. All over Indo Pacific.]

RANGE: Miocene to Recent in West Indies, Panama, and North America. Also Recent on the west coast of Africa and in the Indopacific region. Bathymetric range, from littoral zone to 570 meters (311 fathoms).

ORIGINAL DESCRIPTION: *Eucidaris.* Tubercles à col lisse; trois espèces vivantes; presque toutes les espèces tertiaries; toutes les espèces crétacées moins une (20); quelques jurassiques seulement (*C. Moieri Honorinae, propinqua, marginata, monilifera, multipunctata*); la plupart des triasiques (7). (Pomel.)

SUPPLEMENTARY DESCRIPTION: Pores not conjugate, wall rising into a rounded prominence; pores on peristome in larger specimens more or less distinctly biseriate (not in *metularia*). Madreporite slightly enlarged. Primary spines typically cylindric, terminating in a small crown with a central prominence; the shaft with low, rounded warts arranged in rather distinct longitudinal series. General surface of shaft usually covered with a thick, spongy coat of anastomosing hairs. Sometimes the primaries may be fusiform, tapering to a simple point, sometimes they are very thick, clubshaped. Secondary spines rather appressed. Large globiferous pedicellariae without an end tooth, with or without a limb on the stalk. Small globiferous pedicellariae with a small, but distinct end tooth. Tridentate pedicellariae may occur in two distinct forms, both with long, slender valves. (Mortensen, 1928.)

REMARKS: Pomel mentioned "trois espèces vivantes" in his original description of this genus. Döderlein, 1887, used the genus *Eucidaris* in a modern sense and mentioned *E. metularia* as the first species. This species was considered to be the type of the genus by H. L. Clark, 1909, by Mortensen, and by others. Bather (Ann. and Mag. Nat. Hist., Ser. 8, Vol. 3, p. 88, 1909) stated, "We may well suppose that the 'trois espèces vivantes' of Pomel's list were *Cidaris metularia, C. tribuloides*, and *C. thouarsi*."

This procedure is not in strict conformity with the International Rules of Zoological Nomenclature. However, in view of the fact that nearly all workers on Echinoidea accept *Cidarites metularia* Lamarck as the type of the genus *Eucidaris*, we continue this practice.

(76) Adapted from Mortensen, 1928, p. 321.

Five living species and subspecies of *Eucidaris* were recognized by Mortensen. Two of these occur in the warmer waters of western North America.

Eucidaris cf. **E. thouarsii** Valenciennes

Plate 24, Figures 19-22

The following are references to typical *E. thouarsii.*

Cidaris thouarsii Valenciennes in L. Agassiz and Desor, Ann. Sci. Nat. (Zool), Ser. 3, Vol. 6, p. 326 [typ. err. 324], 1846.

Eucidaris thouarsii Valenciennes, Mortensen, Monogr. Echin. I. Cidaroidea, p. 393, pl. 42, figs. 5-12; pl. 57, figs. 1 and 2; pl. 73, figs. 3-5; pl. 86, figs. 1-7; text figs. 115 (2), 117, 118 (1, 3), 1928. Lower California to Panama and the Galapagos Islands, shore to 45 meters.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 7, pl. 2, figs. 1, 2, 1938. Earlier records cited. ?Miocene, Pliocene to Recent.—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 229, pl. 35, fig. 1, 1948. Gulf of California to La Plata Island, Ecuador. Also the islands off the coast.

TYPE SPECIMEN: Muséum National d'Histoire Naturelle de Paris[77].

TYPE LOCALITY: "Californie. (Neboux.) Gallopagos."

RANGE: ?Middle Miocene in California and Lower California, and ?late Miocene, (Túxpan formation, Vera Cruz), eastern Mexico. Pliocene to Recent. Recent, common in the western Americas from San Felipe Bay near the north end of the Gulf of California to La Plata Island, Ecuador; also Guadalupe Island[78] (C. Limbaugh, coll.), Alijos Rocks and Revillagigedo Islands, Mexico, Cocos Island and Galapagos Islands, from shore to 139 meters (76 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 12163, Pacific Beach, (spines). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach, (spines); Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U.S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943), (spines); Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach, (spines).

ORIGINAL DESCRIPTION: Aires ambulacraires étroites, composées de quatre rangées de granules, dont les deux internes sont à peine développées. Base des tubercles large. Espace granuleux intermédiaire entre les rangées, étroit. Granules assez apparents, peu serrés. Piquants subcylindriques, enflés, très granuleux, rappelant ceux du *C. Blumenbachii.* (Valenciennes.)

REMARKS: The fossils recorded here from the San Diego formation are spines. Many were collected by G. P. Kanakoff at Loc. 305 (LAM), near the Mexican boundary. One of the largest spines measures 5 mm. in diameter. Similar spines were collected by Kanakoff at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street, and at Loc. 122 (LAM), Pacific Beach. Spines collected by Henry Hemphill from Pliocene strata at Pacific Beach are in the collections of the California Academy of Sciences.

These spines have been compared with those of a series of Recent specimens of *Eucidaris thouarsii* in the collections of the California Academy of Sciences. Mr. Fred C. Ziesenhenne likewise compared these specimens with Recent ones in the collections of the Allan Hancock Foundation, and he could detect no essential differences other than those due to weathering. Only spines of the fossil form are known from the Pliocene beds at San Diego; therefore, we adopt the conservative course and record only a provisional identification of the species.

The collections of the Los Angeles Museum include a single incomplete but moderately well preserved plate of a cidarid from Loc. 305 (LAM). Comparing this with plates of Recent species of Cidaridae, Mr. Ziesenhenne concluded that it resembles plates of *Cidaris*, *Histocidaris*, and even *Stereocidaris*, more closely than it resembles *Eucidaris.*

Specimens apparently referable to *E. thouarsii* occur in beds of Pliocene age in the Galapagos Islands and in Imperial County, California, and in beds of late Pliocene and Pleistocene age in the Gulf of California.

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[77] Dr. André Franc, Muséum National d'Histoire Naturelle de Paris, informed us (written communication) that Mr. G. Cherbonnier in that institution made a search for the type specimen of *Cidaris thouarsii* Valenciennes. Mr. Cherbonnier's opinion is that the type may be one of two specimens in the museum which were collected by M. Neboux, but he cannot determine with certainty whether either of these unnumbered and poorly preserved specimens is the type.

[78] Recent discovery of the occurrence of this species at Guadalupe Island and at Alijos Rocks by members of an expedition of the Scripps Institution of Oceanography was called to our attention by Edwin C. Allison.

Many years ago a spine from the Monterey formation of late Miocene age in San Mateo County, California, was submitted by Ralph Arnold to H. L. Clark for identification. The latter stated[79], "I do not think it shows a single feature by which it can be distinguished from *thouarsii*. If it is not *thouarsii*, it is certainly from the ancestor of that species." *Eucidaris thouarsii* was cited by Jackson[80] as occurring in the Miocene Túxpan formation, Vera Cruz, Mexico. Toula[81] mentioned that a species occurring in the Gatun formation of middle or late Miocene age in Panama shows a relationship with *Eucidaris tribuloides* Lamarck and with *E. thouarsii*.

Loel and Corey[82] cited "*Cidaris thouarsii*(?) Valenciennes (Kew)" from beds of middle Miocene age in the Santa Ana and Santa Monica mountains. We have not studied specimens from those areas.

Eucidaris thouarsii galapagensis Döderlein from the Galapagos Islands has thick club-shaped spines with the collar of the primaries somewhat longer than that of typical *thouarsii*. H. L. Clark did not consider this form worthy of recognition, but Mortensen (1928, p. 399, pl. 42, fig. 13; pl. 86, figs. 8-10) believed it to be at least a valid variety and perhaps a distinct species. Both *E. thouarsii* and the form *galapagensis* occur at the Galapagos Islands.

Genus **HESPEROCIDARIS** Mortensen

Hesperocidaris Mortensen, Vid. Medd. Dansk. Nat. For. København, Bd. 85, p. 73, 1928. "Genotype: *Dorocidaris panamensis* A. Agassiz."—Mortensen, Monogr. Echin. I. Cidaroidea, p. 415, 1928. "Genotype: '*Dorocidaris*' *panamensis* A. Agassiz." —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 9, 1938. "Type (by original designation): *Dorocidaris panamensis* A. Agassiz."

TYPE SPECIES (by original designation): *Dorocidaris panamensis* A. Agassiz[83] [Bull. Mus. Comp. Zool., Vol. 32, No. 5, p. 73, pl. 1; pl. 2, fig. 1, 1898. Off Cocos Island, in 66 and in 100 fathoms. Off Galera Point, in 85 and in 112 fathoms. Also illustrated by A. Agassiz, Mem. Mus. Comp. Zool., Vol. 31, pp. 20-23, pls. 1-4; text figs. 3, 12, 22-24, 26-29, 43-45, 1904. Original locality cited. Bathymetric range, 66-112 fathoms. —Mortensen, 1928, pp. 416-419, pl. 18, fig. 8; pl. 73, fig. 8; pl. 82, figs. 23-29; text figs. 124-127, 1928. —H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 230, pl. 35, fig. 2, 1948.]

RANGE: Paleocene to Recent, western America. Recent from the Gulf of California to Galera Point, Ecuador; also Clarion Island, Cocos Island, and Galapagos Islands; in from 55 to 274 meters (30 to 150 fathoms).

DESCRIPTION: Pores not conjugate, wall nearly flat; pores on peristome in single series. Madreporite not enlarged. Primary spines slender, with low granules arranged in longitudinal series; cylindrical, not tapering, but sometimes conspicuously widened and flattened towards the end, the surface covered with a thick, spongy coat of anastomosing hairs. Secondary spines not strongly appressed. Large globiferous pedicellariae without an end tooth and without a limb on the stalk. Small globiferous with a small end tooth. Tridentate pedicellariae of one form only, with slender valves. (Mortensen, 1928, p. 415.)

REMARKS: *Hesperocidaris* resembles *Stylocidaris* (see Mortensen, 1928, p. 334; type, *Cidaris affinis* Philippi) in general characters. The two genera differ, however, in the character of the primary spines. Those of *Stylocidaris* usually taper to a fine point, the hairs on the surface of the shaft are usually simple, sometimes lacking, and the large globiferous pedicellariae possess a well developed limb on the stalk. *Stylocidaris* is essentially an Indo-Pacific genus represented in those waters by about 16 species. Two species occur in the Caribbean and one of them also in the mid-Atlantic and Mediterranean.

So far as known, fossil and Recent species of *Hesperocidaris* occur only in the western Americas.

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(79) Clark, H. L., in Arnold, R., Proc. U. S. Nat. Mus., Vol. 34, No. 1617, p. 359, August 8, 1908.

(80) Jackson, R. T., Proc. U. S. Nat. Mus., Vol. 84, No. 3015, p. 229, 1937.

(81) *Cidaris* sp., Toula, Jahrb. Kais.-Kgl. Geol. Reichsanst., Bd. 58, Heft 4, p. 735, 1909.

(82) Loel, W., and Corey, W. H., "The Vaqueros Formation, Lower Miocene of California. I. Paleontology," Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 22, No. 3, p. 167, December 31, 1932. Also p. 141.

(83) Fred C. Ziesenhenne (verbal communication) pointed out to us that *Stylocidaris houstonia* A. H. Clark (Smithson. Miscell. Coll., Vol. 98, No. 11 (Publ. 3536), p. 12, pl. 4, figs. 10, 11; pl. 5, figs. 12-14, June 2, 1939, "Galápagos Islands: Tagus Cove, Albemarle Island; from the anchor chain in 50 fathoms (91 m.) of water.") is identical with *Hesperocidaris panamensis* A. Agassiz.

Hesperocidaris perplexa H. L. Clark

Plate 24, Figures 6, 7, 9, 10, 12, 14

Tretocidaris perplexa H. L. Clark, Bull. Mus. Comp. Zool., Vol. 51, No. 7, p. 205, pl. 6, figs. 1, 2; pl. 7, figs. 1-4, December, 1907.

Hesperocidaris perplexa H. L. Clark, Mortensen, Monogr. Echin. I. Cidaroidea, p. 421, pl. 42, fig. 14; pl. 73, fig. 7; pl. 82, figs. 30-31, 1928. Gulf of California in 65-70 meters. Clarion Island (locality perhaps not reliable).—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 231, pl. 36, fig. 3, December 29, 1948. South of San Benito Islands and the Gulf of California. Bahia Honda, Panama, north of Gorgona Island, Colombia, and La Plata Island, Ecuador, Recent.

Cidaris sp., Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 7, April 19, 1938. "Pacific Beach," Pliocene.

TYPE SPECIMEN: No. 188, Museum of Comparative Zoology, Harvard University.

TYPE LOCALITY: "Two of the five known specimens of this species were collected by the 'Álbatross' in the Gulf of California on a bottom of coarse sand, in 36-39 fathoms. The other three are said to have been picked up on the shore of Clarion Island, the westernmost of the Revilla Gigedo Islands." According to H. L. Clark (1948) the type locality is "Gulf of California."

RANGE: Middle Pliocene to Recent. Recent from south of the San Benito Islands to Lat. 29°39′N. in the Gulf of California, and from Bahia Honda, Panama, to La Plata Island, Ecuador, in 13 to 110 meters (7 to 60 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1183, Eagle Street, just north of Quince Street, just east of Reynard Way, (spines); Loc. 1401, south slope of Soledad Mountain, first canyon west of Rose Canyon, (spines); Loc. 28892, near Mexican boundary, (spine); Loc. 28893, corner of India and Upas streets, San Diego. (spines). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach, (fragment and spines); Loc. 180, 2220 block on east side of La Jolla Boulevard at intersection with Trias Street, back of excavation, (spine). SAN DIEGO SOCIETY OF NATURAL HISTORY: Pacific Beach, (plate); Loc. 80, south slope of Soledad Mountain, first canyon west of Rose Canyon, (spines); Loc. 150, Pacific Beach, (spines). UNIVERSITY OF CALIFORNIA: Loc. A-8333, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943), (spines).

ORIGINAL DESCRIPTION: Test somewhat flattened; vertical diameter, about .55 h. d.; coronal plates 7 or 8; areolae small, only .60-.65 of horizontal length of plate, distinct and not very deeply sunken; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra about one-third of interambulacra in width; poriferous zones, broad and little sunken; median ambulacral area with a double series of tubercles on each margin, inner much smaller, and between these, 3-6 irregular series of small tubercles which sometimes, but not always, conceal vertical suture; pores nearly horizontal, large, their horizontal diameter much exceeding vertical. Abactinal system about .40 h. d., nearly circular and clearly defined, flat and quite thickly covered with small secondary spines; genital plates rather large, nearly square or somewhat pentagonal, with pores near outer edge; ocular plates more or less triangular, with apex truncated, when in contact with anal system, either wholly excluded, or some, or all except right anterior one, in contact with a large anal plate; anal system about one-half of abactinal, with an external series of 10-12 large plates and 12-15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50-80± such tubercles and each ocular 20-35±. Actinostome small, only about .35 h. d., not at all sunken, closely covered with stout plates, 4 in each interambulacrum and about 10 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often flattened and widened at tip, covered with 14-24 longitudinal series of coarse, sharp granules; actinal primaries much as in Cidaris and nearly smooth; secondaries, long and narrow, but rather thick and often with a deep longitudinal furrow on outer surface at tip, which is thus crescent-shaped in cross-section. Pedicellariae not peculiar; no large globiferous ones were found, but small globiferous and tridentate, like those of *dubia*, are frequent. General color of test decidedly greenish, especially abactinally; miliary spines greenish; secondary spines greenish with a broad longitudinal stripe of deep reddish-purple; primary spines dull grayish with a bright olive-green base and collar. Largest specimen, 50 mm. h. d.; vertical diameter, 27 mm.; abactinal system, 20 mm.; actinostome, 18 mm.; longest spine, 40 mm., 3 mm. thick at base, 5 mm. wide at tip. (H. L. Clark.)

REMARKS: This species, cited as *Cidaris* sp. by the present authors in 1938, is represented by a fairly well-preserved plate from Pacific Beach in the collections of the San Diego Society of Natural History and by numerous spines in this and other collections available to us. Mr. Fred C. Ziesenhenne carefully compared these with a series of specimens in the Allan Hancock Foundation. According to him, if we allow for changes due to weathering and fossilization, these agree in all particulars with specimens of the Recent *Hesperocidaris perplexa* H. L. Clark. Comparison with specimens of the Recent species leads the authors to the same conclusion. A number of spines similar to those mentioned above are present in the collections of the California Academy of Sciences from various localities in San Diego and also in the collection of the Los Angeles County Museum.

H. L. Clark (1948) mentioned that the tests of large adult specimens attain a diameter of about 43 mm. and a height of 25 mm., with primary spines 35 to 43 mm. in length. He pointed out that the spines of this species do not show the characteristic flattening and widening at the distal end until they attain a length of about 30 mm. Some of the fossil spines in the present collections are similarly flattened.

This species differs from the related Recent west American species *H. dubia* H. L. Clark and *H. panamensis* A. Agassiz[84] in the smaller peristome and apical system, in the close tuberculation of the interporiferous zone, and in the distally widened and flattened primary spines. H. L. Clark pointed out (1948) that "the striking and very constant feature of the coloration in *perplexa* is the conspicuous broad, brown longitudinal stripe which occurs on *all* the spinelets." Mortensen considered "the character of the large globiferous pedicellariae lacking the limb on the stalk" to be important in the classification of this species.

Among the spines of *Eucidaris* cf. *E. thouarsii* collected by H. Hemphill from Pliocene beds at Pacific Beach, there are several which in general characters resemble those of *Hesperocidaris panamensis* A. Agassiz. The largest of these (incomplete) measures 34 mm. in length and 3.6 mm. in diameter. These spines were compared by Mr. Fred C. Ziesenhenne with those of Recent specimens of *H. panamensis* in the collections of the Allan Hancock Foundation. He stated that the fossil spines differ only in size from those of the Recent form. The difference in size, and the fact that no test referable to *H. panamensis* has been found, have led us merely to mention their occurrence here rather than to discuss them under a separate caption.

Hesperocidaris merriami Arnold[85] is represented by spines in the Martinez formation, Paleocene, in San Mateo County, California. These are quite similar to the spines of *H. perplexa*, but they bear only 13 or 14 longitudinal rows of spinules. H. L. Clark considered this Paleocene species to be the precursor of *H. perplexa*.

Hesperocidaris lorenzanus Kew[86], described from beds referred by Arnold to the San Lorenzo formation, Oligocene, was based upon spines. The spines are smaller than those of *H. merriami*, smooth toward the base, and ornamented above with fewer (about 10) but much more prominently nodose longitudinal ribs. According to H. L. Clark (quoted by Arnold), this species probably is referable to the same genus as *H. perplexa*.

A characteristic feature of *Hesperocidaris asteriscus* H. L. Clark (1948), from Panama, is said to be the star-like figure formed by the genital plates.

A portion of a spine from Loc. 1400 (CAS), Pacific Beach, differs from spines of *H. perplexa* in possessing more rows of closely compacted spinules. Mr. Ziesenhenne suggested that this might represent a rapidly developing juvenile spine but that it could hardly be referred to *H. perplexa*.

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(84) For reference to this species see p. 104.

(85) *Cidaris merriami* Arnold, Proc. U. S. Nat. Mus., Vol. 34, No. 1617, p. 359, pl. 32, fig. 8, August 8, 1908. "Santa Cruz quadrangle, San Mateo County, locality No. 25, ridge between headwaters of San Lorenzo River and Pescadero Creek." "Martinez formation, lower Eocene."

(86) *Cidaris branneri* Arnold, Proc. U. S. Nat. Mus., Vol. 34, No. 1617, p. 363, pl. 33, fig. 5, August 8, 1908. "Santa Cruz quadrangle, Santa Cruz County, locality No. 109, on Bear Creek, 4 miles above its confluence with the San Lorenzo River." "San Lorenzo formation, Oligocene, upper portion transitional toward Vaqueros formation, lower Miocene." (Not *Cidaris branneri* White, 1888, Brazil, Cretaceous.) Renamed *Cidaris lorenzanus* Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, p. 52, pl. 3, fig. 4, 1920.

Order ARBACIOIDA Gregory

Family ARBACIIDAE Gray

Teeth keeled; ambulacral plates compound, with 3-5 elements in each plate; primordial interambulacral plates present; periproct with (normally) 4 or 5 equal plates; primary tubercles imperforate. (H. L. Clark, 1925.) Late Jurassic to Recent.

Genus ARBACIA Gray

Arbacia Gray, Proc. Zool. Soc. London for 1835, p. 58, June 1, 1835. Original list includes "*Arbacia pustulosa* (*Echinus pustulosus,* Lam.), *Arb. punctulata* (*Ech. punctulatus,* Lam.), &c."—Lambert and Thiéry, Essai Nomencl. Raison. Echinoid., Fasc. 4, p. 270, March, 1914. "Type: *A. pustulosa* Klein (*Cidaris*)."—H. L. Clark, Cat. Rec. Sea-Urchins Brit. Mus., p. 69, 1925. "Type, *Cidaris pustulosa* Leske, 1778 = *Echinus lixula* Linné, 1758. Syst. Nat., ed. 10, p. 664."—Mortensen, Monogr. Echin. II. Bothriocidaroida, Melonechinoida, Lepidocentroida, and Stirodonta, p. 562, 1935. "Genotype: *Cidaris pustulosa* Leske = *Echinus lixula* Linnaeus."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 18, April 19, 1938. Earlier records cited. "Type of the genus (according to H. L. Clark, 1908): *Cidaris pustulosa* Leske."

Synonyms of this genus cited by Mortensen are: *Echinocidaris* Desmoulins, 1835; *Agarites* L. Agassiz, 1841; *Anapesus* Holmes, 1860; *Pygomma* Troschel, 1872.

TYPE SPECIES (designated by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 34, No. 2, p. 67, 1908): "Type-species, *Cidaris pustulosa* Leske, 1778." [*Cidaris pustulosa* Leske, Add. ad Klein, p. 150, pl. 11, figs. A-D, 1778. Also illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7, (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 92; Pt. 2, p. 263, pl. 2, fig. 4; pl. 5, figs. 1-18, 1872. Atlantic Ocean. "Littoral,—125 fathoms." Pt. 3, p. 402, pl. 1g, fig. 5; pl. 2a, figs. 15-33; pl. 5, figs. 19-21; pl. 28, fig. 6; pl. 38, figs. 10a-c, 1873. "Mediterranean; Liberia; Brazil." —Mortensen, Monogr. Echin. II, p. 566, pl. 70, fig. 13; pl. 87, figs. 11, 12, 1935 (placed under *Arbacia lixula* Linnaeus).]

RANGE: Late Miocene[87] to Recent. Pliocene to Recent in the western Americas. Recent on the west and east coasts of the Americas, Angola, Africa, to the Mediterranean, and Tristan da Cunha Island in the south Atlantic. Bathymetric range, intertidal zone to 315 meters (172 fathoms) (according to Mortensen). Most species occur in less than 182 meters (100 fathoms).

DESCRIPTION: Test solid, of medium size, up to c. 70 mm. diameter, low hemispherical or subconical, flattened on the oral side. Ambulacra with compound, 3-geminate plates; pore-zone straight, narrow above the ambitus, conspicuously widened on the oral side. Primary ambulacral tubercles in a regular series throughout. Interambulacra with numerous primary tubercles, arranged in horizontal and vertical series; on the upper side there is mostly a conspicuous naked, but not sunken interambulacral space, only the outer series of tubercles reaching to the apical system, the other series generally disappearing at the ambitus or at some distance from the apical system. No secondary tubercles. Generally the epistroma is conspicuously developed and may be of a characteristic design. Apical system dicyclic or with one to three of the oculars insert. Ocular pores double. Peristome very large, the ambulacra protruding so as to form "ambulacral lips." Gill-slits rather deep and wide. Peristomial membrane naked, with numerous small plates imbedded. Primary spines moderately long, scarcely exceeding diameter of test, straight, cylindrical, stout, often flattened at the end, but not pointed; on the oral spines the cortex-layer is present as a small terminal "shoe" or "cap"; the ambital and upper spines without any cortex-layer. Pedicellariae tridentate, triphyllous and ophicephalous. Sphaeridia single, only one in each ambulacrum, placed in a small pit in the median line, close to the peristomial edge. Spicules usually smooth rods, widened and with some holes in the middle. Colour mostly dark, the denuded test as a rule beautifully coloured, reddish, purplish or greenish. (Mortensen, 1935.)

REMARKS: Six species and one subspecies of this genus were cited by Mortensen as occurring in the seas at the present time. Three species occur in west American waters between Newport Bay, California, and Cape Horn. One of these is well known in the Magellanic region; the other two occur in warm temperate and tropical waters, rarely below 91 meters (50 fathoms).

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(87) Cooke (Jour. Paleo., Vol. 15, No. 1, p. 11, 1941) cited *Arbacia aldrichi* Clark from beds of late Oligocene age, but later he placed this species in the genus *Arbia* Cooke (see Cooke, C. W., U. S. Geol. Surv., Prof. Paper 321, p. 21, 1959).

Arbacia incisa A. Agassiz

Plate 26, Figures 6, 8, 10

Echinocidaris incisa A. Agassiz, Bull. Mus. Comp. Zool., Vol. 1, No. 2, p. 20, August 15, 1863. Guaymas and Panama.

Arbacia incisa A. Agassiz, H. L. Clark, Bull. Amer. Mus. Nat. Hist., Vol. 32, p. 220, 1913. "San Josef" [San José] Island, San Esteban Island, and Agua Verde Bay, Gulf of California.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 19, pl. 4, fig. 1; pl. 30, fig. 13, April 19, 1938. Pliocene to Recent.—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 244, pl. 40, fig. 11, December 29, 1948. Numerous records from Newport Harbor, California, to the Middle Chincha Island, Peru, Recent.

Arbacia stellata (Blainville; ?Gmelin), Mortensen, Monogr. Echin. II, Bothriocidaroida, Melonechinoida, Lepidocentroida, and Stirodonta, p. 575, pl. 68, figs. 8-10; pl. 70, figs. 6-9; pl. 71, fig. 7; pl. 87, figs. 13, 14, February 22, 1935. Lower California to Peru and the Galapagos Islands, Recent.

TYPE SPECIMEN: "Cotype" (according to H. L. Clark), No. 467, Museum of Comparative Zoology, Harvard University.

TYPE LOCALITY: "Guayamas, Panama." According to H. L. Clark (1948, p. 246) the type locality is "Guaymas," Sonora, Mexico.

RANGE: Pliocene to Recent. Recent from Newport, California, (Ziesenhenne[88]), to the Middle Chincha Island, Peru, Lat. 13°39′15″S., from the littoral zone to 91 meters (50 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Pacific Beach.

ORIGINAL DESCRIPTION: Abactinal system very prominent, sutures between the plates well marked; tubercles large, spines short, stout, color yellowish-brown. (A. Agassiz.)

REMARKS: A single small test of an echinoid, 7.6 mm. in diameter and 3.8 mm. high, was collected at Pacific Beach by Professor E. Dean Milow, San Diego State College, who generously presented it to us. Mr. Fred C. Ziesenhenne compared this with young specimens of *Arbacia incisa* in the Allan Hancock Foundation. He stated that the ocular plates, pore pairs, tubercles, and other visible characters of the test, were similar to corresponding structures of the specimens of *A. incisa*. We therefore refer the test to that species.

This species is also known to occur as a fossil in Pliocene beds in Ecuador and probably in the Pliocene strata on Cedros Island, Mexico, and in Pleistocene beds at Magdalena Bay, Lower California, Mexico, and in Ecuador.

Mortensen (1935) presented arguments for placing *Arbacia incisa* in the synonymy of *Echinus stellatus* Blainville [89] and perhaps in the earlier *Echinus stellatus* Gmelin[90]. H. L. Clark (1948) stated, "Nobody knows to what sea-urchin the name *stellatus* was first given." In an earlier paper, however, H. L. Clark[91] also used the name *Arbacia stellata* for the present species. In view of the doubtful application of the name *Echinus stellatus* as used by Agassiz and by Blainville, we use the name *Arbacia incisa*, which is well known to west American authors.

The largest recorded size for this species, cited by H. L. Clark, is a diameter of 60 mm. It is the only species of *Arbacia* in west American waters north of Ecuador. The tests of Recent specimens are readily identified by the reddish patches on the bare interambulacral areas on the aboral surface.

The test of Recent *Arbacia dufresnii* Blainville is greenish on the interambulacral areas. The ocular plates are wide and concave distally, and there are but few spines and tubercles on the aboral interambulacral areas. This species occurs from La Plata, Ecuador, to Puerto Mont on the coast of Chile and at the antarctic island of Booth Wandel and at the Falkland Islands.

The test of *Arbacia spatuligera* Valenciennes lacks red or green coloration, and it has club-shaped spines on the aboral surface. It ranges from Guayaquil, Ecuador, to southern Chile.

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(88) Ziesenhenne, F. C., Bull. South. Calif. Acad. Sci., Vol. 40, Pt. 3, pp. 118-120, September-December, 1941, issued January 31, 1942.

(89) *Echinus stellatus* Blainville, Dict. Sci. Nat., Vol. 37, p. 76, 1825. "J'ai établi cette espèce d'après un individu de la collection du Muséum, confondu à tort avec l'O. piqueté de M. de Lamarck."

(90) *Echinus stellatus* Gmelin, Syst. Nat., ed. 13, Tom. 1, Pars VI, p. 3174, 1788. "Habitat in mari americano." Ref. to "Seb. mus. 3.t.13, f.7."

(91) See Bull. Mus. Comp. Zool., Vol. 52, No. 17, p. 345, October, 1910.

Order ECHINOIDA Claus

Suborder CAMARODONTA Jackson

Family ECHINIDAE Gray

Ambulacral plates compound, typically of 3 elements; ambitus circular; test without sculpturing or pits (H. L. Clark, 1925.) Late Paleogene to Recent. (Durham and Melville.)

Genus LYTECHINUS A. Agassiz

Lytechinus A. Agassiz, Bull. Mus. Comp. Zool., Vol. 1, p. 24, August 15, 1863. Three species cited under the genus. "*Lytechinus carolinus* Ag." "South Carolina, Georgia, and Florida"; "*Lytechinus variegatus* A. Ag." "Cienfuegos, Hayti"; "*Lytechinus atlanticus* A. Ag." "Bermudas."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 23, 1938. "Type of genus (designated by Verrill, 1867): *Echinus variegatus* Leske."—Mortensen, Monogr. Echin. III.2. Camarodonta. I., p. 434, February 22, 1943. "Genotype: *Lytechinus variegatus* (Lamarck)."

TYPE SPECIES (designated by Verrill, Trans. Connecticut Acad. Arts and Sci., Vol. 1, Pt. 2, p. 302, 1867): "The *Echinus variegatus* may be regarded as the type." [Leske, Add. ad Klein, pp. xviii, 149, pl. 10, figs. B, C, 1778. Illustrated by Mortensen, 1943, p. 437, pl. 24, figs. 3-5; pl. 25, figs. 1-12; pl. 53, figs. 1, 6, 7, 11-13 (as *Lytechinus variegatus*). Common over all the West Indian region; north to North Carolina and Bermuda and south to Santos, Brazil.]

RANGE: Early Miocene to Recent. Recent, eastern Pacific, West Indies, west Atlantic, and Cape Verde Islands, in warm temperate and tropical waters, from the intertidal zone to 540 meters (295 fathoms).

DESCRIPTION: Buccal membrane usually heavily plated; a primary tubercle on each ambulacral plate; gill cuts deep; ocular I, and sometimes V, insert, as a rule. (H. L. Clark, 1925.)

REMARKS: *Lytechinus* was included in the family Echinidae by H. L. Clark, who discussed the problems of its classification (1925, pp. 104-105); but Mortensen (1943) placed it in the family Toxopneustidae Troschel. Tests range from small to quite large. The tests usually are low and rounded, and the ambulacra contain trigeminate plates, each with a primary tubercle. There is usually a bare median space in the aboral portion of each interambulacral area.

A specimen from early Miocene strata on Santa Rosa Island, California, was identified by H. L. Clark as very near to *Lytechinus pictus* Verrill, differing only slightly in details of tuberculation. Lack of details on fossil specimens led Mortensen to question whether some should be referred to *Lytechinus*. He mentioned, however, (1943, p. 435) that *L. coreyi* Grant and Hertlein, described from early Miocene beds in California, is probably the forerunner of the Recent west American species.

Mortensen cited ten species and subspecies in his key to the Recent species of *Lytechinus*. These are restricted to warm temperate and tropical waters. The four eastern Pacific species range from Santa Barbara, California, to Ecuador and the Galapagos Islands. The Atlantic species range from North Carolina and Bermuda Island to Santos, Brazil, and one species reaches the Cape Verde Islands.

Lytechinus species

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach.

REMARKS: A fragment of an echinoid test, 40 mm. in diameter, and a piece of a spine, were collected by J. F. Arndt at Loc. 122 (LAM), Pacific Beach. Both bear a general resemblance to *Lytechinus pictus* Verrill[92]. These were examined by Mr. Fred C. Ziesenhenne, who stated that the observable plates, bearing three pore pairs in each arc, and the spine, resemble comparable portions of *L. pictus*. He added, however, that the fossil is larger than any Recent specimen of that species in the collections of the Allan Hancock Foundation.

The fossil specimen is so incomplete and so imperfectly preserved that no illustration is given. It seems desirable, however, to record the presence of the genus *Lytechinus* in the San Diego formation.

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(92) *Psammechinus pictus* Verrill, Trans. Connecticut Acad. Arts and Sci., Vol. 1, Pt. 2, p. 301, June, 1867. "Cape St. Lucas, Cal.,—J. Xantus, (Smithsonian Institution)."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 25, pl. 5, figs. 4-6; pl. 15, figs. 6, 7, 1938. Miocene to Recent.—Mortensen, Monogr. Echin. III. 2. Camaradonta.I., p. 450, pl. 53, figs. 2, 8, 1943.—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 249, pl. 41, fig. 15, 1948. Newport, California, to the Gulf of California and perhaps south to Gorgona Island, Colombia, and La Plata, Ecuador, (although the records of occurrences at the two latter localities may represent *L. panamensis* Mortensen) in 0 to 95 fathoms.

Lytechinus pictus has been recorded as occurring in Pliocene strata on Cedros Island, Lower California, Mexico.

Family **STRONGYLOCENTROTIDAE** Gregory

Ambitus circular; no pits or sculpturing on the coronal plates; ambulacral plates compound, usually with 4 or more elements (rarely 3). (H. L. Clark, 1925). Miocene to Recent.

Genus **STRONGYLOCENTROTUS** Brandt

Strongylocentrotus Brandt, Rec. Actes Séance Publ. Acad. Impér. Sci. St. Petersbourg for 1834, p. 263 (in separate p. 63), issued 1835. Species in original list: *Echinus chlorocentrotus* Brandt (p. 264) and ?*Echinus tuberculatus* Blain. (p. 264).—H. L. Clark, Mem. Mus. Comp. Zool., Vol. 34, p. 352, 1912. "Type-species, *Strongylocentrotus chlorocentrotus* Brandt, l.c., p. 264 (or 64) = *Echinus dröbachiensis* O. F. Müller, 1776."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 31, 1938. Type (by virtual monotypy): *Strongylocentrotus chlorocentrotus* Brandt (= *Echinus dröbachiensis* O. F. Müller).—Mortensen, Monogr. Echin. III. 3. Camarodonta. II., p. 193, October 1, 1943. "Genotype: *Strongylocentrotus chlorocentrotus* Brandt = *drøbachiensis* (O. Fr. Müller)."

Euryechinus Verrill, Proc. Boston Soc. Nat. Hist., Vol. 10, pp. 340, 341, 1866. "A new name must be adopted for the present group, having *E. dröbachiensis* as its type."

TYPE SPECIES [by virtual monotypy, *Strongylocentrotus chlorocentrotus* Brandt, 1835, p. 264 (= *Echinus dröbachiensis* O. F. Müller, Prod. Zool. Dan., p. 235, 1776)] (designated by the International Commission on Zoological Nomenclature in Opinion 208, March 8, 1954): *Echinus drobachiensis* O. F. Müller. [Illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 162; Pt. 2, p. 277, 1872; Pt. 3, p. 441, pl. 4a, figs. 2, 3, 6, 1873. North Europe; North Pacific; northeast America. (Contains extensive synonymy.) —Mortensen, Danish Ingolf-Exped., Vol. 4, Pt. 1, Echin. (1), pp. 162, 165, pl. 1, figs. 5, 6; pl. 2, figs. 3-5; pl. 16, figs. 4, 9, 11, 13, 17, 21, 23; pl. 20, figs. 3-6, 12, 13, 16, 18, 20, 25, 26, 29, 1903. Wide distribution in the North Atlantic and North Pacific Oceans. —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 33, pl. 4, fig. 6; pl. 6, fig. 1, 1938. North Europe; North Pacific; northeast coast of North America. —Mortensen, Monogr. Echin. III.3. Camarodonta. II., p. 198, figs. 92a, b, 93a, 95; pl. 23, figs. 1-11; pl. 69, figs. 1-5, 10, October 1, 1943. (With synonymy.) Circumpolar; to Puget Sound in western North America and to northern Scotland in the Atlantic.]

RANGE: Miocene of Oregon (Arnold). Pliocene to Recent in California and Lower California. Recent, North Pacific, and one species circumboreal and ranging to northern Scotland and to Chesapeake Bay, from the littoral zone to 1600 meters (875 fathoms); off California, littoral zone to 125 meters (68 fathoms).

ORIGINAL DESCRIPTION: Aculei teretes, subulati, conformes et magnitudine tantum inaequales. (Brandt.)

SUPPLEMENTARY DESCRIPTION: Pore pairs 4 to 10, but usually not more than 7; valve of globiferous pedicellariae with a powerful end tooth but no lateral teeth. (H. L. Clark, 1925.)

REMARKS: *Strongylocentrotus* is widespread in the northern seas at the present time. This genus is characteristic of cold and temperate waters, but in west American waters ranging south to San Bartolomé Bay (Turtle Bay), Lower California. Mortensen included ten living species in the genus, only one, the type of the genus, ranging through the Arctic seas and into the North Atlantic as far as Scotland. This distribution, states Mortensen, strongly points toward a North Pacific origin of *Strongylocentrotus*.

Species attributed to *Strongylocentrotus* have been cited from Miocene strata in France, but according to Mortensen these probably are referable to *Paracentrotus* Mortensen. Cooke (1941, p. 19) indicated that the record (Clark and Twitchell, 1915) of the occurrence of *Strongylocentrotus dröbachiensis* in the Caloosahatchie beds of Pliocene age in Florida needs confirmation.

Two species of *Strongylocentrotus* occur off California in shallow depths, generally among rocks up to the intertidal zone but sometimes to depths of 161 meters (88 fathoms). Swan[93] recently discussed the species of this genus occurring in the waters of the northeast Pacific.

(93) Swan, E. F., "The Strongylocentrotidae (Echinoidea) of the Northeast Pacific," Evolution, Vol. 7, No. 3, pp. 269-273, September 30, 1953. See also "Regeneration of Spines by Sea Urchins of the Genus Strongylocentrotus," Growth, Vol. 16, pp. 27-35, 1952.

The species from southern California described as *Strongylocentrotus fragilis* Jackson[94] has been referred by some later workers to *Allocentrotus* Mortensen; this occurs in deeper water, often 73 to 110 meters (40 to 60 fathoms) but sometimes as deep as 1170 meters (640 fathoms) (H. L. Clark, 1948.)

The diagnostic characters of this genus cited in Mortensen's key to the family Strongylocentrotidae are as follows: ambulacra gradually constricted on the oral side, at the peristomial edge distinctly narrower than the interambulacra; spicules of the globiferous pedicellariae simply bihamate; test very fragile.

KEY TO THE SPECIES OF STRONGYLOCENTROTUS

A. Primary spines very long (50-60 mm.); test usually exceeding 75 mm. in diameter; 2 rows of primary tubercles in each interambulacrum decidedly larger than adjacent ones; arcs of 9-10 pore pairs, steeply sloping ..... *franciscanus*

B. Primary spines short, usually not exceeding 15-20 mm.; test usually not exceeding 75 mm. in diameter; 2 rows of primary tubercles in each interambulacrum not exceptionally larger than adjacent ones; arcs of usually 8 pore pairs, approaching horizontal arrangement ..... *purpuratus*

Strongylocentrotus franciscanus A. Agassiz

Plate 19, Figure 28

Toxocidaris franciscanus A. Agassiz, Bull. Mus. Comp. Zool., Vol. 1, p. 22, August 15, 1863. San Francisco, California. Recent.

Strongylocentrotus franciscanus A. Agassiz, A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 163 (in part), 1872; Pt. 3, p. 442 (in part); pl. 5b, figs. 1, 2; pl. 7, figs. 10, 10a, 1873. Localities cited from Puget Sound to San Diego, California, Recent.—Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, table opp. p. 52, 1920. "San Diego," "Pliocene." (Not pl. 4, figs. 1a-c = *?Echinometra van-brunti* A. Agassiz).—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 34, fig. 14; pl. 2, fig. 6; pl. 6, fig. 3, 1938. "San Diego (Kew)".—Mortensen, Monogr. Echin. III.3. Camarodonta.II., p. 242, figs. 106-110; pl. 28, figs. 1-7; pl. 29, figs. 1-4; pl. 30, figs. 2-3; pl. 31, figs. 1-2; pl. 32, figs. 1-3; pl. 61, figs. 10, 15-19, 23, October 1, 1943. Kodiak Island, Alaska, to Cedros Island, Lower California, and northern Japan, Recent.

TYPE SPECIMEN: "Cotype" (according to H. L. Clark, 1948) No. 1686, Museum of Comparative Zoology, Harvard University.

TYPE LOCALITY: "San Francisco," California. Recent.

RANGE: Middle Pliocene to Recent. Recent from Kodiak Island, Alaska, to Cedros Island and Thurloe Point, Lower California, Mexico. (?)Hakodate, Japan (see Mortensen, 1943, p. 246). From the littoral zone to 125 meters (68 fathoms) (Mortensen).

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego (Kew; Grant and Hertlein). CALIFORNIA ACADEMY OF SCIENCES: Loc. 12163, Pacific Beach. LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). UNIVERSITY OF CALIFORNIA: Loc. A-8333, locality same as Loc. 305 (LAM). UNIVERSITY OF CALIFORNIA AT LOS ANGELES: corner of Market Street and Euclid Avenue, San Diego (fragment) (B. Brattstrom coll.).

ORIGINAL DESCRIPTION: This species grows to a very large size. High coronal plates, large openings for suckers. Pores arranged in arcs of nine pairs. Two very prominent rows of large tubercles in interambulacral space. The large tubercles of ambulacra of same size as secondary of interambulacra. Spines long, tapering gradually, equalling in length two thirds the diameter of test. (A. Agassiz.)

REMARKS: Portions of two small tests, the larger about 21.5 mm. in diameter, were collected by Henry Hemphill at Loc. 12163 (CAS), Pacific Beach. A comparison of these with specimens of *Strongylocentrotus franciscanus* of similar size reveals no appreciable differences.

A fragment of a test, (UCLA coll.), 25.5 mm. in altitude and 15 mm. in diameter, from Market Street and Euclid Avenue in San Diego, appears to represent a portion of a basal ambulacrum of the present species. In the size and arrangement of the pore pairs and in the slope of the arcs, this fragment is very similar to corresponding parts of Recent specimens of *Strongylocentrotus franciscanus*.

A fragment of a spine 14.8 mm. in length from Loc. A-8333 (UC), from southwestern San Diego County, appears to be referable to this species. It occurs with a fragment of a spine of *Hesperocidaris*.

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[94] *Strongylocentrotus fragilis* Jackson, Mem. Boston Soc. Nat. Hist., Vol. 7, p. 128, January, 1912. ". . . at Catalina Island, off the southern California coast. . ." Also "dredged off the coast of southern California and Oregon in depths of 124 to 339 fathoms."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 34, pl. 29, fig. 1, 1938. Vancouver Island, British Columbia, to Point Santa Eugenia, west coast of Lower California in deep water.—Mortensen, Monogr. Echin. III.3. Camarodonta. II., p. 255, pl. 30, figs. 10-17; pl. 61, figs. 4, 5, 7, 11, 12, 14, text figs. 117-119, October 1, 1943 (as *Allocentrotus fragilis*). Ca. 50-1150 meters.

Spines of *S. franciscanus* also are present in collections of the Los Angeles County Museum from this locality, Loc. 305 (LAM).

The tests of large specimens of *Strongylocentrotus franciscanus* attain a diameter of 160 mm., and some have been recorded which, with the spines, measured a foot in diameter. The spines of this species are light reddish, brownish, or occasionally purple; on young specimens the tips are white but not banded.

Strongylocentrotus franciscanus differs from *S. purpuratus,* with which it sometimes occurs at the present time, in that the test is much larger, the primary spines are much longer (50 to 60 mm.), and the arcs of pore pairs are more nearly vertical and consist of 9 or 10 rather than about 8 pore pairs. Furthermore, in the midzone of each interambulacrum are two rows of very large tubercles, each row flanked on each side by a row of smaller tubercles: thus each coronal plate has three prominent tubercles, the middle one largest. The corresponding tubercles on *S. purpuratus* are much more nearly uniform in size. Also, *S. franciscanus* has fewer coronal plates: at a diameter of 60 mm. it has 16 or 17, whereas *S. purpuratus* of the same size has about 28 to 30. Mortensen considered *S. franciscanus* to be closely related to *S. nudus* A. Agassiz, of Japan.

Mortensen (1943, p. 242-247) gave a full discussion of the morphology and distribution of this species. He pointed out that individuals living in surf have spines shorter and thicker than are those of individuals living in calm water.

Swan[95] mentioned that this species, in the Puget Sound region, often occurs abundantly a few feet below tide level on vertical faces of rock. He stated that it occurs on intertidal rocky areas on San Juan Island and Lopez Island, Washington, often with *S. purpuratus* and *S. dröbachiensis* as well as with what are probably hybrids of these species. *S. franciscanus* occurs abundantly in rocky places along the coast of northern and central California, generally in deeper tide pools than does *S. purpuratus.* It is said to have been used for food at times by the Indians and Greeks along the coast of British Columbia.

Strongylocentrotus purpuratus Stimpson

Plate 19, Figure 29

Echinus purpuratus Stimpson, Boston Jour. Nat. Hist., Vol. 6, p. 526, April, 1857. "Near San Francisco."

Strongylocentrotus purpuratus Stimpson, Arnold, U. S. Geol. Surv., Prof. Paper 47, p. 28, 1906. "Pacific Beach," "San Diego formation," Pliocene. W. B. Clark and Twitchell, U. S. Geol. Surv., Monogr. 54, p. 223, 1915. "San Diego formation (upper part), Pliocene."—Kew, Univ. Calif., Publ. Bull. Dept. Geol., Vol. 12, No. 2, opp. p. 52, p. 58, 1920. "Pacific Beach, San Diego County," Pliocene.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 37, pl. 4, figs. 4 and 5; pl. 6, fig. 2; text figs. 13 and 15, 1938. "Pliocene.—San Diego, California." Also earlier records cited.—Mortensen, Monogr. Echin. III.3. Camarodonta.II., p. 236, figs. 102b, 103b, 105; pl. 26, figs. 1-8; pl. 27, figs. 5, 7-9; pl. 32, fig. 4; pl. 61, figs. 6, 20-22, 24, October 1, 1943. Vancouver Island, and perhaps Sitka, Alaska, to Cedros Island, Lower California, from littoral zone to about 20 meters.

TYPE SPECIMEN: No. 2495, United States National Muesum.

TYPE LOCALITY: "Found at low-water mark on rocky ocean shores near San Francisco." California.

RANGE: Questionably in the middle Miocene of Oregon ("cf." Arnold, 1906); Pliocene to Recent in California. Recent from Sitka, Alaska (Rathbun; see Mortensen, 1943, p. 241), and Puget Sound, Washington, to Cedros Island, Lower California, Mexico, from the littoral zone to about 20 meters (11 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego formation (Arnold; Clark and Twitchell); Pacific Beach (Kew); San Diego, earlier records (Grant and Hertlein). LOS ANGELES COUNTY MUSEUM: Loc. 153, cliff 50 feet above sea level, south of the end of Loring Street, Pacific Beach; Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian, (spines) (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

ORIGINAL DESCRIPTION: Form depressed. Outline somewhat pentangular. Ambulacral areas of the same width as the interambulacrals; (sometimes even wider;) with eight pairs of pores in each of the very oblique rows, which are separated from each other by rows of small tubercles. Interambulacral area with six rows of larger tubercles, between which smaller ones are interspersed; the tubercles of the two rows next within the exterior ones are largest. Auricles slender. Spines of moderate length, rather stout and blunt. Color, deep purple. Diameter, 2 1/2 inches; height, 1 1/3 inch. (Stimpson.)

[95] Swan, E. F., Evolution, Vol. 7, pp. 270, 271, 1953.

REMARKS: A portion of a single somewhat crushed test, 79.5 mm. in diameter and approximately 38 mm. in altitude, in the collections of the Los Angeles County Museum, is referable to this species. The character of the tubercles as well as the nearly horizontal arrangement of the pore pairs agrees with the corresponding portions of tests of Recent specimens of *Strongylocentrotus purpuratus.*

This specimen came from Loc. 153 (LAM), in a cliff 50 feet above sea level at Pacific Beach. According to the information concerning the locality, there was an element of doubt in the mind of the collector, W. C. Woynar, as to whether the specimen came from beds of Pliocene or of Pleistocene age. However, the brown indurated matrix in which the specimen was embedded is exactly similar to that of the Pliocene strata in that area, and accordingly we consider the specimen to be of Pliocene age.

Spines referable to *Strongylocentrotus purpuratus* also are in a collection of the Los Angeles County Museum from Loc. 305 (LAM), near the Mexican boundary.

This is a common purple sea urchin along the west coast of the United States. Occasionally adult, and especially young, specimens may be green, or the spines may be banded reddish and white. The test is often about 50 to 60 mm. in diameter but occasionally is larger. Swan mentioned specimens from San Juan Island, Washington, which measured from 89 to 99 mm. in diameter. The spines are much shorter than those of *S. franciscanus,* usually not exceeding about 20 mm. in length. The test is smaller than that of *S. franciscanus,* and there are usually about 8 pore pairs in each arc rather than 9 to 10, and these arcs are more nearly horizontal. Furthermore, the primary tubercles on the interambulacral areas of *S. purpuratus* are more nearly the same size as the adjacent ones than are those of *S. franciscanus,* and there are also more numerous coronal plates.

Swan[96] discussed the occurrence of this species in the Puget Sound region and mentioned that specimens occur there which appear to be hybrids between *S. purpuratus* and *S. dröbachiensis* and between *S. purpuratus* and *S. franciscanus.* The same author[97] pointed out that the regenerated spines of *S. purpuratus* are purple instead of the green color which juvenile specimens may have. Also, this species has a great preference for areas of rough water, and the test is tougher and heavier than those of *S. dröbachiensis* and *S. franciscanus;* consequently, it is best fitted for survival if torn loose and washed over rocks in the surf. According to Swan the spines regenerated by *Strongylocentrotus* do not have the same number of wedges or cycles as do the original spines.

Mortensen (1943, p. 236-242) gave a comprehensive discussion of the morphology and characteristics of this species. He stated that he had never seen hybrids between *S. purpuratus* and *S. dröbachiensis* and that he considered *S. purpuratus* to be quite a distinct species.

Mortensen (1943, p. 240) doubted the statement that *S. purpuratus* has the ability to bore cavities in rocks. Irwin[98] has shown that this species as well as *S. franciscanus* does form such cavities. She reported that on a pier near Santa Barbara, California, these urchins occupied circular depressions in steel piling and that the surface of the steel was rust-free and shiny beneath them and thus constantly exposed to the corrosive action of the sea water. Branner[99] long ago pointed out that even the hardest rocks are bored by sea urchins in Brazil.

The food of this species consists of algae and other organic material which it finds on the rocks. Some early accounts mention that this species was at one time sold in the markets of San Francisco, where it was purchased for food by Italian residents.

Family **ECHINOMETRIDAE** Gray

Ambitus more or less elliptical; no pits or sculpturing of coronal plates; ambulacral plates compound, with 3-19 elements, but usually more than 4; oculars exsert or becoming insert in sequence V, I, IV (not I, V, IV as usual). (H. L. Clark, 1925.) Middle Eocene to Recent.

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(96) Swan, E. F., Evolution, Vol. 7, p. 270, 1953.

(97) Swan, E. F., Growth, Vol. 16, pp. 32-34, 1952.

(98) Irwin, M., "Steel-Boring Sea Urchins," Pac. Discovery (Publ. Calif. Acad. Sci.), Vol. 6, No. 2, pp. 26, 27, 3 illustr., March-April, 1953.

(99) Branner, J. C., "Syllabus of a Course of Lectures on Elementary Geology," (Stanford University, California) ed. 4, p. 246, fig. 57, also pl. 18, 1912.

Genus **ECHINOMETRA** Gray

Echinometra Gray, Ann. Phil., Vol. 26 (n.s. 10), p. 426, 1825 (as of Bryerius [Breynius, 1732]). Species in original list: *E. lucunter* Linnaeus, *E. atratus* Klein, and *E. mammillatus* Klein.—H. L. Clark, Cat. Rec. Sea-Urchins Brit. Mus., p. 142, 1925. "Type, *Echinus lucunter* Linné."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 39, April 19, 1938. Type as indicated by Lambert and H. L. Clark.—Mortensen. Monogr. Echin. III.3. Camarodonta. II., p. 352, 1943. "Genotype: *Echinometra lucunter* (Linnaeus)."

Synonyms of this genus cited by Mortensen are: *Ellipsechinus* Lütken, 1864; *Plagiechinus* Pomel, 1883; *Mortensenia* Döderlein, 1906. There is an *Echinometra* of Meuschen, 1778, but this name has not been generally used.

TYPE SPECIES (designated by Lambert, Mém. Soc. Paléo. Suisse, Vol. 37, p. 48, 1911, and by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 34, p. 370, 1912): *Echinus lucunter* Linnaeus. [Syst. Nat., ed. 10, p. 665, 1758. "*Habitat in* O. Indico." Ref. to Gualtieri, Index Test. Conchyl., pl. 107, fig. C (as *Echinus ovalis*, etc.), 1752. Also illustrated by Mortensen, 1943, p. 357, figs. 172-175, 177; pl. 41, figs. 1-5; pl. 42, figs. 12-14; pl. 43, figs. 1-13; pl. 44, fig. 9; pl. 64, figs. 17, 20-24. Florida to Desterra, Brazil; West Indies; Bermuda; St. Helena; Dakar to Angola, Africa.]

RANGE: Eocene[100] (Nummulitique de l'Inde) to Recent. Recent, in very warm temperate and tropical waters in the Pacific, Atlantic, and Indo-Pacific, from the intertidal zone to about 53 meters (29 fathoms).

DESCRIPTION: Test usually elongately oval, rather strong, moderately large to large, white or with tinge of purple or greenish; ambulacral plates of 4 to 8 elements; periproct with numerous plates; ambulacra with 3 pore pairs to each arc at the peristomial edge, the number increasing to 4 to 10 pore pairs above; auricles usually large; the primary spines moderately long, pointed, sometimes clavate, varying from brown to black, purple, or white. (Adapted from Mortensen and H. L. Clark.)

REMARKS: Adult members of this genus can usually be separated from those of *Strongylocentrotus* by the elongately oval test and by the large auricles. Juvenile forms may be but slightly elongated.

About six species and two or three varieties of this genus occur in the seas at the present time. Three species, *Echinometra insularis* H. L. Clark, *E. oblonga* Blainville, and *E. van-brunti* A. Agassiz occur in eastern Pacific waters.

The present authors (1938) pointed out that the genus *Echinometra* is represented in the Pliocene of Ventura County, California, by a specimen illustrated by Kew[101] under the name of *Strongylocentrotus franciscanus*. This specimen appears to be referable to *Echinometra van-brunti* A. Agassiz. The latter species also has been recorded as occurring in beds of late Pliocene age at Santa Barbara, California. The species described under the name of *Heliocidaris stenopora* H. L. Clark, from Acapulco, Mexico, is now believed to be identical with *Echinometra van-brunti*.

Echinometra species

Plate 26, Figures 4, 5

Echinometra sp., Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 41, April 19, 1938. "Lower beds of the San Diego Pliocene at Pacific Beach."

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1413, lower beds of the Pliocene section at Pacific Beach.

REMARKS: A small, slightly crushed test 19.2 mm. in maximum diameter and 8.3 mm. in height, is in the collections of the California Academy of Sciences from Loc. 1413 (CAS), from Pliocene beds in the lower portion of the section exposed at Pacific Beach. The late H. L. Clark stated that the species was undeterminable but that the test appeared to be referable to the genus *Echinometra*. This generic assignment was recently confirmed by Mr. Fred C. Ziesenhenne at the Allan Hancock Foundation in Los Angeles.

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(100) See remarks by Mortensen, 1943, p. 355.

(101) *Strongylocentrotus franciscanus* A. Agassiz, Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, pl. 4, figs. 1a-c, 1920.

Order **CLYPEASTEROIDA** L. Agassiz

Family **DENDRASTERIDAE** Lambert

Medium-sized to large, flattened, usually well-developed internal supports; petals well formed, a few isolated pores outside petals; paired petals more or less closed, anterior petal more widely open; outer member of pore-pair elongated; interambulacrum 5 discontinuous on oral surface; interambulacra nearly as wide as ambulacra at ambitus; basicoronal interambulacral plates larger than ambulacral plates; 4 genital pores; periproct inframarginal to supramarginal; ambulacral food grooves bifurcating or trifurcating just outside basicoronal plates. (Durham, 1955.) Pliocene to Recent, Pacific Coast of North America and Japan.

KEY TO THE GENERA OF DENDRASTERIDAE

A. Apical system usually decidedly eccentric posteriorly; paired petals usually partially closed; margins of test moderately thin..... *Dendraster*

B. Apical system only slightly eccentric posteriorly; paired petals usually open; margins of test thick and rounded..... *Merriamaster*

Genus **DENDRASTER** L. Agassiz

Dendraster L. Agassiz, in Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 7, p. 135, 1847. Only species "*exeentricus* Agass.—*Echinarachnius excentricus* Val., Zool. Venus, pl. 10, Californie (Neboux).—Mus. Paris."—H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, p. 69, 1914. "Type, *Scutella excentrica* Eschscholtz."—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 4, p. 319, 1914. "Type: *D. excentricus* Eschscholtz (*Scutella*)." See also Fasc. 9, p. 584, 1925.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 78, 1938. "Type of the genus (by monotypy): '*exeentricus* Agass.—*Echinarachnius excentricus* Val., Zool. Venus. pl. 10, Californie'."—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, pp. 100, 158, 1955. "Type species: *Dendraster excentricus* L. Agassiz = *Scutella excentrica* Eschscholtz = *Echinarachnius excentricus* Valenciennes, monotypic."

Echinarachnius A. Agassiz. (in part), Illustr. Cat. Mus. Comp. Zool., No. 7, (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 107; Pt. 2, p. 315, 1872; Pt. 3, p. 524, 1873.

Not *Echinarachnius* Gray, 1825.

TYPE SPECIES (by monotypy): "*exeentricus* Agass. —*Echinarachnius excentricus* Val., Zool. Venus. pl. 10, Californie." [= *Scutella excentrica* Eschscholtz, Zool. Atlas, Heft 4, p. 19, pl. 20, figs. 2a-c, 1831. "An der Küste der Insel Unalaschka, am Kamtschatischen Meere." —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 84, figs. 16, 17, 1938 (with synonymy). —Mortensen, Monogr. Echin., IV.2. Clypeastroida. II, p. 382, fig. 222, pl. 60, figs. 1-5; pl. 61, figs. 1, 6; pl. 63, fig. 3, December 30, 1948. —Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, figs. 1d, 4c, 5b, 11, 20, 21a, 21b, 26j, 33, 1955.]

RANGE: Early Pliocene to Recent. Most abundant in late Pliocene: known to occur from central California to the Gulf of California. Recent from the island of Unalaska, Alaska, to near Cape San Lucas, Lower California, Mexico. (Latter locality cited by H. L. Clark, 1948.) From the intertidal zone to about 91 meters (50 fathoms), perhaps occasionally deeper.

DESCRIPTION: Medium-sized to large, flattened; apical system often posteriorly excentric, raised; margins of test moderately thin; paired petals moderately closed, anterior petal elongated, more open than paired petals; a few isolated primary pores outside petals; periproct inframarginal, close to margin, between second and third pair of post-basicoronal plates; peristome central; ambulacral food grooves complexly developed, usually extending onto aboral surface, usually strongly developed posteriorly; basicoronal plates relatively small, interambulacral plates about twice as large as ambulacral plates; interambulacra all discontinuous on oral surface, separated by a pair of ambulacral plates; 3 or 4 post-basicoronal interambulacral plates to column on oral surface; posteriorly 5 or 6 and anteriorly 7 or 8 pairs of post-basicoronal ambulacral plates on oral surface. (Durham, 1955.)

REMARKS: The test of this genus is quite distinct from that of any other genus: it is characterized by the eccentric apical system with elongated anterior petal, by the thin margins, and by the inframarginal periproct. It is easily separated from *Scutellaster* Cragin by the eccentric apical system and the inframarginal rather than supramarginal periproct. *Scutellaster* Cragin is an earlier name for *Anorthoscutum* Lambert and Thiéry and for *Calaster* Kew. The synonymy of this genus has been discussed by Durham[102].

(102) Durham, J. W., "Scutellaster and Anorthoscutum," Jour. Paleo., Vol. 27, No. 1, pp. 147-149, 1 fig., January, 1953.

Eighteen species and subspecies of this genus have been recorded from the Pliocene and Pleistocene of California and Lower California. Fossil forms described since our paper on Echinoidea in 1938 are *Dendraster granti* Durham, from Pliocene strata on the east coast of Lower California, and *D. elsmerensis* Durham, from southern California.

Four species and one subspecies occur in west American waters. In addition to *Dendraster excentricus* Valenciennes and its variety *elongata* H. L. Clark, which were mentioned in our earlier paper, H. L. Clark (1948) has described three others. These are *Dendraster laevis* from north of Santa Barbara Island, California, in 27 to 37 meters (15 to 20 fathoms), *D. mexicanus* from Rosario Bay, Lower California, in 27 meters (15 fathoms), and *D. rugosus* from the Bay of San Sebastian Vizcaino, Lower California, in 31 meters (17 fathoms). The latter species appears to be identical with *D. vizcainoensis* Grant and Hertlein, which originally was described from Quaternary beach deposits at the same bay.

Durham (1955, p. 159), suggested that in *Dendraster* the eccentricity of the apical system and the degree of greater posterior development of the food grooves of a particular species may be correlated with the position assumed by individuals of the species, whether on edge, slightly tilted, or lying flat. He suggested that noneccentric species are probably those which lie flat upon the sea bottom.

On the basis of a statistical analysis of variation, especially in degree of eccentricity, Raup[103] concluded that two ecological races of *Dendraster excentricus* were recognizable. Individuals occurring in sheltered bays were less eccentric than those occurring on open coasts. However, he found no systematic geographic variation based upon this character.

There is certainly much variation in many of the species in this genus, but the characters relied upon for specific differentiation by Kew, by Woodring, and by Stewart, taken together with the stratigraphic occurrence of the specimens, appear to justify such specific discrimination.

H. L. Clark (1948) reported specimens of *Dendraster excentricus* from the coast of Oregon that measured 75 mm. in length, 80 mm. in width, and 12 to 14 mm. in height. A large specimen of *Dendraster venturaensis* Kew, collected by Margaret Bennett and C. M. Carson from strata of late Pliocene age on the ridge west of Coles Canyon, Ventura County, California, measures 100 mm. in length (anteroposterior), 112 mm. in width.

Individuals of *Dendraster* often live on fine sandy bottoms over which tidal currents flow, crowded together, more or less steeply inclined, and with the anterior fourth of the test buried in the sand. They occur abundantly from intertidal sands to a depth of about 37 meters (20 fathoms) and then become less abundant to a depth of about 91 meters (50 fathoms) or perhaps occasionally deeper.

Observations on pigments of *Dendraster excentricus* and *D. laevis* have been recorded by Goodwin and Fox[104].

KEY TO THE SPECIES OF DENDRASTER

A. Apical system only slightly eccentric posteriorly; petals slightly raised ..... *casseli*

B. Apical system decidedly eccentric posteriorly; petals not raised

a. Margin thin; petals usually narrowly open at end; anterior odd petal very broad; test usually wider than long

b. Apical system very eccentric; posterior petals diverging and forming nearly a straight line ..... *ashleyi*

bb. Apical system less eccentric; posterior petals diverging and forming a decidedly obtuse angle ..... *ashleyi ynezensis*

aa. Margin moderately thick; posterior petals widely open at end; anterior odd petal not exceptionally broader than the others; test often as long as wide or longer and usually not exceeding 45 mm. in length ..... *gibbsii humilis*

(103) Raup, D. M., "Dendraster: A Problem in Echinoid Taxonomy," Jour. Paleo., Vol. 30, No. 3, pp. 685-694, figs. 1-4, May, 1956.

(104) Goodwin, T. W., and Fox, D. L., "Some Observations on Pigments of the Pacific Sand Dollars, *Dendraster excentricus* and *Dentraster* [*Dendraster*] *laevis*," Experimentia, Vol. 11, No. 7, pp. 270-276, 1955. See also Univ. Calif. Scripps Inst. Oceanogr., Contrib. for 1955, New Ser., No. 773, pp. 353-359, figs. 1-4, July, 1957.

Dendraster ashleyi Arnold

Plate 21, Figures 1-3, 6; Plate 22, Figures 1, 3; Plate 26, Figure 9

Echinarachnius ashleyi Merriam, Arnold, U. S. Geol. Surv., Bull. 322, p. 58, pl. 24, figs. 6, 7, 1907.

Scutella ashleyi Arnold, J. P. Smith, Calif. State Mining Bureau, Bull. No. 72, p. 38, 1916. "San Diego and lower Fernando formations of the coastal region of southern California."

Dendraster ashleyi Arnold, Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, pp. 84, 85, 1929. "San Diego Pliocene."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 80, pl. 11, fig. 1; pl. 22, fig. 5 (reproduction of original figure); pl. 30, fig. 4, 1938. "1½ kilometers west of Cockatoo Grove, and about 7 kilometers east of Chula Vista"; "north and also west side of Chollas Valley"; "east of Balboa Park, San Diego."—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 59, 1944. "Just west of Cockatoo Grove," Pliocene.—Woodring, U.S. Geol. Surv., Prof. Paper No. 222, pp. 104, 106, 1950. "San Diego district. Inland localities." "San Diego formation." -Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1954 (1955). "San Diego formation."

TYPE SPECIMEN: No. 165,259, United States National Museum.

TYPE LOCALITY: "Graciosa Ridge, near Orcutt," California, "Fernando (Pliocene)." ["Graciosa member of the Careaga on Graciosa Ridge" (Woodring, 1950, p. 68).]

RANGE: Middle Pliocene in central and southern California and northern Lower California.

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego (J. P. Smith; Hertlein and Grant; Woodring); north and west sides of Las Chollas Valley, San Diego; and east of Balboa Park, San Diego (Grant and Hertlein). CALIFORNIA ACADEMY OF SCIENCES: Loc. 1175, 1½ kilometers west of Cockatoo Grove and about 7 kilometers east of Chula Vista; (cf.) Loc. 1405, street cut 0.2 mile southwest of Alamo Drive and Center Street, east San Diego; Loc. 28883, 0.4 mile north of Broadway extension (Federal Avenue) on Fairmount (47th Street) (form approaching *ynezensis*); Loc. 28884, embankment on Windsor Drive where Tourmaline Street would intersect if projected; Loc. 28890, 0.4 mile north of Broadway on Fairmount Avenue. LOS ANGELES COUNTY MUSEUM: Loc. 106, back of house 3030 on west side of Reynard Way, San Diego; Loc. 296, street cut on northwest side of Fairmount extension, 0.4 mile north of intersection with Broadway, on west side of Las Chollas Valley, San Diego [approximately same as Loc. 28883 (CAS)]; Loc. 306, on east side of Euclid Avenue, between Federal Boulevard and intersection of Euclid and Home avenues, San Diego; Loc. 311B, about 15 feet above base of bluff on recent road cut at Loc. 311A, on Windsor Drive; east gate of Navy Hospital, San Diego; above barnacle bed, at southwest corner of intersection of Home and Fairmount avenues, San Diego; east side of 2400 block on Euclid Avenue, San Diego.

This species was first illustrated and named, without description, by Arnold. The first formal description of a typical specimen was given by Kew (Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, pp. 115-116, September 28, 1920) as follows:

DESCRIPTION: Test of medium size. Measurements of specimen No. 11043 [Univ. Calif. Coll.]: anteroposterior diameter 62.5 mm., transverse diameter 74 mm., greatest height 6 mm. Markedly thin. Marginal outline subquadrate, the posterior margin being broadly truncated; transverse diameter the greater, with its greatest width in the posterior portion of the test. Upper surface rises gently to the summit, which is posterior to the center of the test and in front of the apical system; greatest elevation within the radius of the length of the petals. Apical system situated far back near the posterior margin. Madreporite pentagonal in outline, with four genital pores opposite the four anterior corners. Lateral petals not symmetrical, the anterior rows of pores in each petal being curved to a greater degree than those of the posterior rows. Petals of the bivium relatively short, and diverging so as to form with their axes an angle of nearly 180 degrees. Poriferous areas comparatively wide, each being about one-half the width of the interporiferous area. Petals of the trivium of the same length; lateral ones somewhat narrower than the odd anterior one. Poriferous areas of the anterior lateral petals equal to about one-half to one-third the width of the interporiferous area; poriferous areas of the odd petal exceedingly narrow, each being about one-eighth the width of the interporiferous area. Inferior surface very slightly concave to the peristome. The latter is small and round. Dichotomously branching ambulacral furrows extend in well marked lines from the peristome to the margin, but become less distinct toward their extremities, especially those of the odd anterior set. Periproct small, subcircular, inframarginal, and placed about twice its own diameter from the edge of the test. Fine tubercles entirely cover the test. The test of this species is relatively more elevated in the younger than the older specimens. (Kew.)

REMARKS: Typical specimens of *Dendraster ashleyi* differ from *D. gibbsii* and other species of the genus *Dendraster*, by their very thin margins, the very broad curvature of the posterior margin, the very eccentric apical system, and the divergence of the petals of the bivium to form nearly a straight line. This latter feature is not so pronounced on Arnold's figure of the type specimen as in most specimens. The odd anterior petal (III) is usually wider than the others, and all the petals are usually only narrowly open at the ends.

This species occurs in the San Diego formation at several localities in the San Diego area. A specimen from Loc. 1175 (CAS), 1½ kilometers west of Cockatoo Grove and about 7 kilometers east of Chula Vista, is definitely referable to *Dendraster ashleyi,* as are a number of specimens collected by G. P. Kanakoff and J. F. Arndt at various localities in the San Diego area. One such specimen collected by Arndt on Euclid Avenue measures 66 mm. in anteroposterior diameter, 72.8 mm. in transverse diameter.

Kew suggested that *Dendraster ashleyi* probably is a descendent of *D. gibbsii;* but Woodring (1950, p. 103) stated that, despite the very eccentric apical system, the thin test suggests closer relationship to *D. coalingaensis* Twitchell[105].

Durham (1955, p. 157) pointed out that two separate lineages appear at about the same time at the base of the Pliocene. These are represented by *Dendraster gibbsii,* with thick margins and an inframarginal periproct, and *D. elsmerensis* Durham[106] with thin margins and a marginal periproct.

Some specimens of *Dendraster ashleyi* bear a general resemblance to *D. pentagonalis* Israelsky[107], which was described from beds of Pliocene age on Cedros Island, Lower California; but they differ from that species in the thinner margins, the generally more eccentric apical system, the large size of the odd anterior ambulacral petal, and the usually less decidedly pentagonal outline of the test.

According to Woodring, *Dendraster ashleyi* is abundant in the Graciosa member of the Careaga sandstone in the Santa Maria district of southern California. Dibblee[108] reported finding it more abundant in the lower Careaga sandstone in Santa Barbara County in the district where he studied the geology.

In addition to its occurrence in western San Diego County and in Santa Barbara County, *Dendraster ashleyi* has been recorded from Pliocene strata in California in the Sargent oil field in Santa Clara County and also in San Benito County; it also is reported at Turtle Bay and on terraces east of San Quintin, Lower California, Mexico.

Dendraster ashleyi ynezensis Kew

Plate 21, Figures 4, 5; Plate 22, Figures 2, 4, 6, 8; Plate 26, Figure 7

Dendraster ashleyi var. *inezanus* Kew (Ms), Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 1, p. 15, November 20, 1919. From a soft tan and gray sandstone on the north side of the Santa Ynez River, Fernando formation, Pliocene. [No description or figure.]

Dendraster ashleyi ynezensis Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, p. 116, pl. 36, figs. 2a, 2b, September 28, 1920. Santa Ynez River district, Santa Barbara County, California. Upper Fernando formation, upper Pliocene.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 81, pl. 9, fig. 7, 1938. Various localities in San Diego region.—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 59, 1944. "Chula Vista district," Pliocene.—Hertlein and Grant, Calif. State Div. Mines Bull. 170, chapter 2, p. 60, 1954 (1955). "San Diego formation."

TYPE SPECIMEN: No. 11334, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "Santa Ynez River district, Santa Barbara County, California, Univ. Calif. Loc. 3128." "Upper Fernando formation, Upper Pliocene." [According to Woodring (1950, p. 68), the type apparently came from the "upper Santa Ynez Valley in strata presumably of Careaga age."]

RANGE: Middle Pliocene in southern California.

OCCURRENCE IN THE SAN DIEGO FORMATION: Soledad Mountain; Swift Canyon near Boundary Street; Las Chollas Valley above Market Street Bridge; "cf." from road cuts on Alamo Drive and Center Street, north side of upper Las Chollas Valley; off Cherokee Street, on the right side of canyon in old railway embankment; near corner of Thirty-fifth Street and Market Street extension, San Diego (all cited by Grant and Hertlein). CALIFORNIA ACADEMY OF SCIENCES: Loc. 1177, road cut on west side of hill just east of corner of Haines Street and Tourmaline Street, Pacific Beach district; Loc. 1543, ¼ mile east of Fairmount Avenue, in bottom of canyon just south of Laurel Street; Loc. 28884, embankment on Windsor Drive, where Tourmaline Street would intersect if projected, Pacific Beach; Loc. 33218, near Maple and Haller streets, San Diego; Loc. 36384, about two feet

(105) *Dendraster coalingaensis* Twitchell in Clark and Twitchell, U.S. Geol. Surv., Monogr. 54, p. 196, pl. 90, figs. 2a-c, 1915. Upper portion of Etchegoin formation, Pliocene. See also Stewart, R. B., in Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 81, pl. 10, figs. 6-9, 10, 11, 12; pl. 39, fig. 7 ("cf."); pl. 45, figs. 1, 2, 3, 4 (var.), 1941.

(106) *Dendraster elsmerensis* Durham, Amer. Jour. Sci., Vol. 247, p. 50, fig. 2F, pl. 1, figs. 2, 3, 4, 6, January, 1949. From "Loc. A4457—apparently in SW¼ of NE¼ of Sec. 8, T 3N, R 15W, San Bernardino Base and Meridian. From hillside on northwest side of stream, about 200 yards upstream from point where contact of Pico formation and basement cross the stream. Collected from 0′ to 25′ above base of Pico formation. In association with numerous molluscs and *Astrodapsis fernandoensis* Pack."

(107) *Dendraster pentagonalis* Israelsky, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 11, p. 380, pl. 69, figs. 3, 4a, 4b, November 7, 1923. "Cedros Island, Baja California." "Pliocene."

(108) Dibblee, T., Calif. State Div. Mines, Bull. 150, p. 46, 1950.

above conglomerate at base of San Diego formation in road cut on east side of Cabrillo Freeway nearly opposite Mercy Hospital; not localized (No. 181, Chas. Sternberg coll.). LOS ANGELES COUNTY MUSEUM: Loc. 106, behind house 3030, west side of Reynard Way, San Diego; Loc. 107, 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; Loc. 123, bluff 100 yards east of Market Street at level of 34th Street (which does not go through at this point); Loc. 127, shell stratum 5 feet thick, Market Street extension in Encanto, 1¼ miles south of Euclid Avenue, San Diego; Loc. 176, at south end of Juniper Street, at crossing of 31st Street, turn right on dirt road leading to Wabash Canyon, on both sides of canyon; Loc. 294, silt back of house No. 3550 Dove Street, San Diego; Loc. 301, exposure of San Diego formation silt, 50 feet long and 10 to 15 feet high, inside east gate of Naval Hospital 4 feet above road (which is parallel to fence), 200 yards west from lowest part of Florida Street, below Balboa Park, San Diego; Loc. 307, near west end of Hayes Avenue if projected to near road under bridge; Loc. 311B, about 15 feet above base of bluff on recent road cut at Loc. 311A, on Windsor Drive, Pacific Beach district; Loc. A-2862, "Near San Diego"; east side of 2400 block on Euclid Avenue, San Diego (J. F. Arndt, coll.); southwest corner of Fairmount and Home avenues, above barnacle bed, also one specimen from barnacle bed, San Diego. SAN DIEGO SOCIETY OF NATURAL HISTORY: Loc. 23, road cut on west side of hill just east of corner of Haines Street and Tourmaline Street, Pacific Beach district; Loc. 80, south slope of Soledad Mountain, first arroyo west of Rose Canyon highway; Loc. 80A, just west of Loc. 80. Also numerous other localities in and near San Diego.

ORIGINAL DESCRIPTION: This is very closely allied to *Dendraster ashleyi* (Arnold) because of its wide odd anterior ambulacral petal and great angular divergence of the petals of bivium, but differs in that the apical system is less eccentric, and in that the test has a more nearly elliptical outline, the transverse diameter being the greater. Its size is usually larger than that of *D. ashleyi*. (Kew.) [The illustration of the type is indicated as approximately natural size and measures approximately 71 mm. in length, 85 mm. in width, 6.5 mm. in height.]

REMARKS: The less eccentric apical system and less divergent angle of the bivium can usually be relied upon to separate this subspecies from typical *D. ashleyi*. This subspecies often attains a very large size; one specimen from Las Chollas Valley above Market Street bridge, San Diego, measures 100 mm. in length, 115 mm. in width, and about 9.5 mm. in height.

This subspecies occurs abundantly in the San Diego formation at various localities and is the echinoid most commonly found in Pliocene beds in the San Diego area.

Through the courtesy of Mr. George P. Kanakoff of the Los Angeles County Museum, we have had the privilege of examining about 75 specimens of this subspecies collected from Pliocene beds in and near San Diego. These reveal that there is considerable variation in size of test, in degree of eccentricity of the apical system, and in size of angle of the bivium. Some of these specimens closely resemble the form illustrated as *D. ashleyi* by Woodring (1950, pl. 20, fig. 1), who remarked that they closely approached the subspecies *ynezensis*.

A series of 17 specimens of *Dendraster* was collected by Kanakoff at Loc. 106 (LAM), on the west side of Reynard Way in San Diego. Seven of these are referable to *D. ashleyi* and 10 to the subspecies *ynezensis*. The average measurements of these were as follows: for *D. ashleyi*, length 54.5 mm., width 68.2 mm., distance of apical system from posterior end 12.8 mm.; for *D. ashleyi ynezensis*, length 58 mm., width 63.1 mm., distance of apical system from posterior end 16.4 mm.

One specimen, 77.5 mm. in length and 86.5 mm. in width, from Loc. 107 (LAM), still retains many of the spines, especially on the oral side. These spines are about 2.6 to 3 mm. in length. They are somewhat greater in diameter and a little longer than those of the Recent *D. excentricus*.

Four specimens from Loc. 294 (LAM) have very thin margins. The apical system is similar to that of the present subspecies. One small specimen (pl. 22, fig. 2) from this locality has a rounded outline (length 20.5 mm., width 20.6 mm.) and an eccentric apical system as in large forms of *D. ashleyi ynezensis*.

A large specimen, typical of this subspecies, collected by Kanakoff from a bluff east of Market Street (at level of 34th Street), measures 81 mm. in length, 92 mm. in width, approximately 10 mm. in height (convexity), with the apical system approximately 22.4 mm. from the posterior margin.

Several specimens of this subspecies, furnished us by E. Dean Milow, were collected about two feet above the conglomerate at the base of the San Diego formation in a road cut on the east side of the Cabrillo Freeway nearly opposite Mercy Hospital.

Some specimens from the San Diego area are intermediate between *Dendraster ashleyi* and the subspecies *ynezensis* and could perhaps be referred to either of these forms. However, most specimens fall into one category or the other.

Dendraster casseli Grant and Hertlein

Plate 22, Figure 7

Dendraster casseli Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 81, pl. 1, figs. 1-3; pl. 30, fig. 3, April 19, 1938.

TYPE SPECIMEN: No. 6193, Type Collection, Department of Paleontology, University of California at Los Angeles.

TYPE LOCALITY: "from Loc. 356 (U.C.L.A.), at head of ravine in SE. corner of Sec. 10, T.4N., R.17W., S.B.B. & M., about 0.2 mi. N. of corner, in the *Dendraster* bed, elevation 1300 feet by contour (U. S. Geol. Surv. topog. map of Santa Susana quadrangle)." Los Angeles County, California. "Upper half of the Pliocene."

RANGE: Middle Pliocene in southern California and San José Island, Gulf of California, Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 107, 100-foot bluff with scattered concretions in clay quarry at end of Arroyo Drive, San Diego.

ORIGINAL DESCRIPTION: Test of medium size; outline subcircular, the posterior margin more broadly curved, also slightly more broadly curved at distal ends of the anterior paired ambulacra; margin thin but dorsal (abactinal) surface inflated, ventral (actinal) surface slightly concave; apical system slightly excentric posteriorly, and slightly posterior to the highest portion of test, genital pores 4; ambulacra subpetaloid, narrow, long, the poriferous zones gradually becoming obsolete distally, the nonporiferous zones raised, sometimes conspicuously, sometimes the entire ambulacra raised, especially the proximal portion; bivial angle but slightly larger than angles between ambulacra of the trivium; pore-pairs conjugate; primary tubercles imperforate, in depressed scrobicules; ambulacral furrows but slightly depressed but variable, bifurcating close to the peristome; periproct small, nearly circular, on actinal surface close to margin. Length of holotype, 50.7 mm.; width, 51.1 mm.; height, approximately 8.4 mm. (Grant and Hertlein.)

REMARKS: The test of *Dendraster casseli* is characterized by its slightly eccentric apical system and by its long, narrow, open, and raised ambulacral petals.

Two specimens of this species, their actinal surfaces cemented together by matrix, were collected by G. P. Kanakoff at Loc. 107 (LAM), at the end of Arroyo Drive in San Diego. The larger of these measures 56.9 mm. in length, 60.8 mm. in width. The specimens compare favorably with the type specimen of *D. casseli,* differing chiefly in that petals I, II, IV, and V are somewhat more contracted at their distal ends. The difference, however, is believed to be individual variation or perhaps a feature concomitant with the larger size of the specimen.

This is the first record of the occurrence of this species in the San Diego formation. It also is known to occur in the upper half of the Pliocene section in northern Los Angeles County and in Pliocene strata on San José Island in the Gulf of California.

Dendraster gibbsii humilis Kew

Plate 22, Figures 5, 9

Dendraster gibbsii humilis Kew, Univ. Calif. Publ. Dept. Geol., Vol. 12, No. 2, p. 124, pl. 25, figs. 3a, 3b, September 28, 1920. "Coalinga district, Fresno County, California . . . and Santa Maria district, California."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 88, pl. 1, fig. 4, 1938. Also "Pacific Beach, San Diego, California."

TYPE SPECIMEN: No. 11379, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "Coalinga district, Fresno County, California, Univ. Calif. Loc. 2100." [From "a locality in the Jacalitos Hills west of the Kettleman Hills" according to Stewart, 1941, p. 80.]

RANGE: Middle Pliocene in southern California and northern Lower California.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 12164, Pacific Beach (Grant and Hertlein).

ORIGINAL DESCRIPTION: This seems to be an intermediate form between *Dendraster gibbsii* (Rémond) and *D. ashleyi* (Arnold), differing from the former in having a thinner test with angulated margins; from the latter it differs in that the odd anterior petal is narrower, about the same width as the anterior lateral pair, and in that the apical system is less eccentric. (Kew.)

REMARKS: There is little to be added to the above description. Typical specimens differ from *Dendraster gibbsii*[109] in particulars which justify a subspecific name for this form.

This subspecies is known from Pliocene strata at Pacific Beach, San Diego, by two specimens collected by Henry Hemphill. The apical system of these is not so eccentric as that of the type illustrated by Kew; but the general outline of the test, the petals that are widely open at the end, and the similarity in size of the odd anterior petal to the others, all are characters that lead us to refer these specimens to *D. gibbsii humilis*.

In addition to its occurrence in Pliocene beds at San Diego, this subspecies has been recorded as occurring in Pliocene strata in the Coalinga district, the Santa Maria district, and the Purisima formation in California, and at Cedros Island, at Turtle Bay, and near Scammon Lagoon, Lower California, Mexico.

Genus **MERRIAMASTER** Lambert

Merriamaster Lambert, Rev. Crit. Paléozool., Quinzième année [Vol. 15], No. 1, p. 64, January, 1911. "Type" of the genus: "*Scutella Perrini* Weaver [Weaver]."—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 4, p. 312, 1914, and Fasc. 9, p. 581, 1925.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 64, 1938. "Type of the genus (by original designation and by monotypy): *Scutella perrini* Weaver."—Mortensen, Monogr. Echin. IV.2. Clypeastroida, p. 396, December 30, 1948. "Genotype: *Merriamaster Perrini* (Weaver)."—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, p. 161, 1955. "Type species: of *Merriamaster, Scutella perrini* Weaver, orig. desig."

Orchoporus Lambert and Thiéry, Essai Nomencl. Raison, Echinid., Fasc. 4, p. 293, March, 1914. Type by monotypy, sole species, *Orchoporus koehleri* Lambert and Thiéry. (New name for *Astrodapsis* sp. indet., Arnold, U.S. Geol. Surv., Bull. 396, p. 162, pl. 28, figs. 5, 5a, 1909. "Upper Etchegoin formation." (P. 37) From Loc. 4708 "On 1,245-foot hill 4 miles southeast of northwest end of Kettleman Hills, east side of sec. 32, T. 21S., R.17E. *Arca* bed in upper *Mya* zone, or uppermost beds.") (See also Stewart, in Woodring, Stewart, and Richards, 1941, p. 82.)

?*Twitchellia* Lambert, Rev. Crit. de Paléozool., Vol. 20, No. 4, p. 171, 1916. ". . . avec deux espèces, *T. Merriami* Anderson (*Astrodapsis*), type du genre (fig. 7) et *T. Packi*, à pétales courts, l'impair plus ouvert que les autres (fig. 8)." The figures referred to are by W. B. Clark and Twitchell, U.S. Geol. Surv., Monogr. 54, pl. 85, 1915. Type of the genus (by original designation, as above): *Scutella* (?) *merriami* (Anderson) of W. B. Clark and Twitchell, fig. 7 only. Not *Astrodapsis merriami* Anderson, Proc. Calif. Acad. Sci., Ser. 3, Geol., Vol. 2, pp. 193-194, pl. 14, figs. 33, 34, December 4, 1905.

TYPE SPECIES (by original designation): *Scutella perrini* Weaver. Reference given to Arnold and R. Anderson, U. S. Geol. Surv., Bull. 398, pl. 50, figs. 1 and 2, 1910. From Loc. 4712 "east of Zapato Creek, one-half mile south of Adolph Kreyenhagen's house, SW. 1/4 SE. 1/4 sec. 8, T.22S., R.16E. Variable pebbly sand, with many fossils. *Pecten coalingaensis* zone, or upper middle beds." Upper Miocene or lower Pliocene. [Pliocene]. [*Scutella perrini* Weaver, Univ. Calif. Publ., Bull. Dept. Geol., Vol. 5, No. 17, p. 273, pl. 12, fig. 2, December 28, 1908. Type locality, "In beds presumably of Miocene age near Coalinga, California." [Late Pliocene.] —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 68, pl. 15, fig. 11; pl. 30, fig. 9, 1938. —Stewart in Woodring, Stewart, and Richards, U. S. Geol. Surv., Prof. Paper 195, p. 81, pl. 46, figs. 1, 2, 4, 7, 10, 12, 1941. *Pecten* and *Trachycardium* zone in Kettleman Hills, San Joaquin County, California. San Joaquin formation, late Pliocene. —Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, p. 161, figs. 4f (p. 79), 35c (p. 161), 1955.]

RANGE: Middle Pliocene of California and northern Lower California.

DESCRIPTION: Test ovate, moderately flattened, moderately thick, the margins rounded; genital pores 4 (none between petals I and V); apical system slightly eccentric posteriorly; ambulacral petals open and extending to the margin, usually slightly raised; test with large, well-developed tubercles: ambulacral food grooves on adults bifurcate about one-third the distance from the peristome to the margin; periproct just inframarginal, often on a slight rostrum; internal radial supports simple, moderately developed; internal concentric supports only slightly developed.

REMARKS: A discussion of this genus was given by the present authors in 1938, and recently Durham gave an extensive discussion of its morphology. Stewart pointed out that the type of *Orchoporus*

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(109) *Scutella gibbsii* Rémond, Proc. Calif. Acad. Nat. Sci., Vol. 3, p. 13, April, 1863. "Kern Lake, Buena Vista County." Gabb cited as considering the species to be of Miocene age. See also Grant and Hertlein, 1938, p. 88, pl. 14, fig. 6, 1938. Earlier records cited. Also Stewart, in Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 80, pl. 40, figs. 2-4; pl. 42, figs. 1-5; pl. 43, figs. 1, 2, 4, 5; pl. 44, fig. 6, 1941.

The recorded occurrence of this species at Lituya Bay, Alaska, by Dall (in Mertie, U.S. Geol. Surv., Bull. 836, p. 130, 1931) is referable to a different species, as indicated by Stewart, 1941, p. 109, footnote 32. It has recently been named *Echinarachnius alaskense* by Durham (Jour. Paleo., Vol. 31, No. 3, p. 628, pl. 72, figs. 6, 8, May, 1957.)

is a young specimen of *Merriamaster perrini*, and although the original figure is said to be deceiving, it appears probable that *Twitchellia* likewise can be referred to *Merriamaster*.

Durham (1955) placed *Merriamaster* in the Dendrasteridae and *Astrodapsis* in the Echinarachniidae. However, *Merriamaster* appears to be more closely related to *Astrodapsis* than to *Dendraster*. Mortensen (1948, p. 397) mentioned that *Merriamaster* may probably represent a transition between *Astrodapsis* and *Dendraster*, but he also added that "in some cases of the very numerous species of this group from the American west coast it may be questionable to which of the three said genera they should be referred."

The test of *Merriamaster* differs from that of *Astrodapsis*[110] in the slightly eccentric apical system, in the somewhat shorter and generally less elevated petals, and in the bifurcation of the food grooves about one-third the distance from the peristome to the margin. In *Astrodapsis* the apical system is central, the petals are decidedly raised above the surface, and the central food grooves extend unbranched to the margin.

Merriamaster differs from *Dendraster* in the less eccentric apical system, the more open and usually raised petals, the thicker and more rounded margins, the fewer interior concentric supports, the greater number of plates on the oral surface, and the usually larger spine bases.

Only five or possibly six species in California and Lower California appear to be referable to the genus *Merriamaster*. Two of these occur in Pliocene beds in the San Diego area. In the San Joaquin Valley this genus is known to occur only in the San Joaquin formation of late Pliocene age. The genus *Merriamaster* is not definitely known to occur in western North America north of Half-moon Bay, California.

KEY TO THE SPECIES OF MERRIAMASTER

A. Outline subpentagonal; petals rather narrow and decidedly elevated at and near apex; shallow interambulacral depressions present on abactinal surface; tubercles rather small.....*pacificus*

B. Outline broadly oval; petals moderately broad and only slightly elevated; interambulacral depressions on abactinal surface only slightly developed; tubercles large.....*israelskyi*

Merriamaster cf. **M. israelskyi** E. K. Jordan and Hertlein

Plate 23, Figures 10, 12, 14

The original reference to typical *M. israelskyi* is Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 424, pl. 27, figs. 4, 6, July 22, 1926.

Astrodapsis israelskyi E. K. Jordan and Hertlein, Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 73, 1938. "lower beds in the Pliocene at Pacific Beach, San Diego"; "Cabrillo Canyon, Balboa Park, San Diego."

TYPE SPECIMEN: No. 2086, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Bernstein's abalone camp, Cedros Island, Lower California; upper Pliocene."

RANGE: Middle Pliocene in southern California, and Cedros Island and Turtle Bay, Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: (cf.) Loc. 107, 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 124, 15 feet below floor level of Snyder Continuation school, San Diego. SAN DIEGO SOCIETY OF NATURAL HISTORY: Cabrillo Canyon, Balboa Park, San Diego.

ORIGINAL DESCRIPTION of *A. israelskyi*: Test small; subcircular to oval in outline, not greatly elevated, the upper surface rather flat; margin thick, evenly rounded and entire; apical system central, or slightly posterior, the apex of the test slightly anterior to the center of the madreporic area; madreporic area pentagonal, with four genital pores; petals narrow, slightly elevated, widely open, and extending nearly to the margin; rows of pores at first diverge, then at about half the distance to the margin they

(110) *Astrodapsis* Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, No. 6, p. 315, apparently issued approximately April 25, 1857. Only species cited, *Astrodapsis antiselli* Conrad. "Monterey Co., Cal." Middle Tertiary. Illustrated by Conrad, U.S. Pac. R.R. Repts., Vol. 7, Palaeo., p. 196, pl. 10, figs. 1, 2, 1857. *"Estrella"* [Monterey County], California.—Richards, Trans. San Diego Soc. Nat. Hist., Vol. 8, No. 9, pl. 7, figs. 1a, 1b, 1935. (Type specimen illustrated).—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 70, pl. 16, figs. 3, 4, 1938.—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, pp. 104, 167, fig. 3d (p. 78), fig. 22a (p. 105), 1955.

converge slightly, after which they continue toward the margin parallel or very slightly divergent; outer row of pores more pronouncedly sinuous than inner; interambulacral areas relatively broad, little depressed, flat, sloping gently from the apex toward the margin; inferior surface concave toward the center; mouth central, large, subpentagonal in outline; ambulacral furrows not distinct, but branching close to their origin at the peristome and extending nearly to the margin; periproct fairly large, situated on ventral surface and a little less than its own diameter from the margin; tuberculation prominent, the tubercles rather large and distantly spaced, those on the inferior surface perhaps even more prominent than those above. Anteroposterior diameter 37.5 mm.; transverse diameter 35.3 mm.; greatest elevation 7.9 mm. (E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 424, pl. 27, figs. 4, 6, July 22, 1926.)

REMARKS: The authors of this species recognized its general relationship to *"Dendraster" perrini*, the type species of *Merriamaster*. Study of a series of specimens of *"Astrodapsis" israelskyi* leads the present authors to place it in the genus *Merriamaster*. This assignment is based upon the slight eccentricity of the apical system and especially on the fact that the central food grooves on the oral surface of the test do not extend to the margin but branch about a third the distance from the peristome to the margin. Assuming that bifurcation of the food grooves is a generic character of *Merriamaster*, *Astrodapsis kewi* E. K. Jordan and Hertlein[111] also belongs in *Merriamaster*.

The specimens from San Diego referred to *Merriamaster* cf. *M. israelskyi* range in length from about 25 mm. to 43.3 mm. None of these are perfectly preserved; but in observable characters these specimens agree in general with the type of this species, and they closely resemble specimens from San Bartolomé Bay (Turtle Bay), Lower California.

In two specimens from Balboa Park in the collection of the San Diego Society of Natural History, the larger one 43.3 mm. long and 43.4 mm. wide, the actinal surface is moderately well exposed. In outline of test, character of tubercles, and thickness of margin, these specimens are similar to *M. israelskyi*.

Four imperfect and about a dozen smaller and quite imperfect specimens of *Merriamaster* were collected by George Kanakoff at Loc. 124 (LAM), with specimens of *M.* cf. *M. israelskyi*. The greatest diameter measurable among these is 71.8 mm. The outline, the moderately thick margins, and the tuberculation on the oral surface, where observable, do not differ greatly from those of *M. israelskyi*. The incompleteness and poor preservation of these specimens prevent positive identification. It is possible that some of these might be referable to *M. pacificus*. Specimens from other localities in San Diego, none of them well preserved, appear to be referable to *M.* cf. *M. israelskyi*.

Merriamaster israelskyi differs from *M. pacificus* in the ovate rather than subpentagonal outline of the test, the broader less elevated petals, the coarser tuberculation, the slightly thicker margins, and the very slight development of the interambulacral depressions on the aboral surface.

In an earlier paper we mentioned the possibility that Smith's record of *Astrodapsis fernandoensis* in the "San Diego" region might be referable to *M. israelskyi* or to *M. pacificus*[112].

In *Merriamaster israelskyi* the apical system is almost central in the type specimen and in most others and the margin is moderately thick, whereas in *M. perrini* the apical system is moderately eccentric and the margin is very thick. The ovate outline and much less eccentric apical system separate *M. israelskyi* from *M. arnoldi* Twitchell[113].

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(111) *Astrodapsis kewi* E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 425, pl. 27, figs. 2, 3, July 22, 1926. "Bernstein's abalone camp, Cedros Island, Lower California; upper Pliocene."

(112) "Smith (1916, p. 38) recorded the geologic occurrence of *A. fernandoensis* as 'San Diego and Lower Fernando formations of the coastal regions of Southern California' but we have not seen any specimens of this species in any of the collections from the San Diego Pliocene available to us. Possibly Smith's record was based upon imperfect specimens of *Astrodapsis israelskyi* or *Merriamaster pacificus* which have been discovered there since Smith's paper was issued." (Grant and Hertlein, 1938, p. 73, footnote.)

(113) *Dendraster arnoldi* Twitchell, U.S. Geol. Surv., Monogr. 54, pp. 192-193, pl. 88, figs. 4a-d, 1915. "Near A. Kreyenhagen's place and south of Lucille well, 2 miles southwest of Coalinga in Coalinga district, California." "Etchegoin formation," Pliocene.—Stewart in Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 81, pl. 39, fig. 5; pl. 41, fig. 3; pl. 46, figs. 3, 5, 6, 8, (cf.) 9, 11, (cf.) 13, 1941 (as *Dendraster* (*Merriamaster*) *arnoldi*). According to Stewart, "Kew's *D. coalingaensis* Twitchell is *D.* (*Merriamaster*) *arnoldi* Twitchell."

Merriamaster pacificus Kew

Plate 23, Figures 1-6, 11; Plate 25, Figure 6; Plate 26, Figure 11

Dendraster pacificus Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, list opp. p. 52, p. 128, pl. 33, figs. 1a-c, September 28, 1920. "Cedros Island, Lower California; Pacific Beach, San Diego County, California." "San Diego formation, Upper Pliocene."—E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 420, 1926. "Pliocene of Pacific Beach" (Kew's record.)

Merriamaster pacificus Kew, Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 67, pl. 20, fig. 9, 1938. "Pacific Beach, San Diego"; and "Cabrillo Canyon, San Diego."—Hertlein and Grant, Calif. Jour. Mines and Geol., Rept. 35 of State Mineralogist, p. 70, 1939. "Cabrillo Canyon," "San Diego formation," Pliocene.—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 59, 1944. "Cabrillo Canyon," San Diego, Pliocene.—Woodring, U.S. Geol. Surv., Prof. Paper 222, p. 104, "Pacific Beach and inland," p. 106, "San Diego district," "San Diego formation," 1950.—Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1954. "San Diego formation."

Dendraster (*Merriamaster*) *pacificus* Kew, Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 113, 1941. "Pacific Beach."

TYPE SPECIMEN: Holotype[114] No. 448, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Pacific Beach, San Diego County, California." "San Diego formation, Upper Pliocene."

RANGE: Middle Pliocene in southern California and northern Lower California.

OCCURRENCE IN THE SAN DIEGO FORMATION: Pacific Beach (Kew; E. K. Jordan and Hertlein; Grant and Hertlein); Cabrillo Canyon, Balboa Park, San Diego; Pacific Beach and inland (Woodring). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 308, 0.2 mile north of intersection of Harbor Drive and Tourmaline Street, Pacific Beach; Loc. 309, northwest of Chalcedony Street, gully in second canyon east of Kate Sessions School, Pacific Beach. UNIVERSITY OF CALIFORNIA: Loc. 3069, ¼ mile north of Crystal Road, near top of cliff just below heavy conglomerate bed, Pacific Beach (L. Phillips coll.).

ORIGINAL DESCRIPTION: Test small. Average measurements of holotype: anteroposterior diameter 36 mm., transverse diameter 35 mm., greatest height 8.3 mm. Outline subpentagonal. Upper surface depressed, and rising gently from a moderately thickened and rounded margin to a low apex situated slightly anterior to the center of the test. Very indistinct depressions are present in the interambulacral areas. Apical system slightly eccentric to the posterior. Petals of the trivium of the same length and longer than those of the bivium, extending a little over half the distance from the apical system to the margin. Rows of pores diverge for about one-half the length of the petal and then continue in parallel lines to the end, the outer rows converging but little in the distal portion of the petal; a few sporadic pores extend beyond nearly to the edge of the test. Odd anterior petal is slightly narrower than the lateral petals. Petals are more or less elevated, this being a distinctive character. Four large genital pores and five perforated radial plates are present in the apical system. Lower surface concave to the peristome; the latter is subcircular in outline and posterior to the center of the test, being opposite the apical system. Distinct, broad ambulacral furrows present, branching dichotomously a short distance from the mouth and continuing to the margin. Tuberculation prominent; consists of a few large scrobicular tubercles on the petals; smaller secondary tubercles are present over the remainder of the upper surface, interspaced with numerous milliaries; the under side is covered by a few large tubercles of the same size as on the petals, and interspaced with numerous smaller ones. Periproct round, inframarginal, and situated a distance about equal to its own diameter from the edge of the test. (Kew.)

REMARKS: Diagnostic features of this species are the pentagonal outline, the slightly eccentric apical system, the narrow petals, decidedly raised near the apex, and the shallow interambulacral depressions on the aboral surface.

A series of 14 specimens collected by J. F. Arndt at Loc. 122 (LAM), Pacific Beach, range from 20 to 33.8 mm. in maximum diameter. Most of these are slightly crushed or imperfect; but all have the outline, shape and height of petals, and other characters of *Merriamaster pacificus*. A series of 25 specimens collected by Mr. G. P. Kanakoff at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach, range from 18 to 38.6 mm. in maximum diameter. Some of these are quite well preserved and are typical of this species.

(114) Two "Cotypes" were originally cited: No. 448, Department of Geology Type Collection, California Academy of Sciences, and No. 11340, Invertebrate Paleontology Collection, University of California. Measurements of the "holotype" also were given. These measurements agree with those of the specimen illustrated as "Cotype" No. 448, and therefore it is here selected as the holotype.

Most of the other specimens of this species that we have seen from San Diego, except the holotype, are poorly preserved and furnish no additional information concerning this species.

A specimen in the collections of the San Diego Society of Natural History collected at Pacific Beach by Frank Stephens measures 25.5 mm. in length, 27.4 mm. in width, 7.8 mm. in height. The oral surface is encrusted with sediment, but the position of the apical system and shape of the petals are those of *M. pacificus*. Two specimens from Cabrillo Canyon in San Diego, in the collections of the same institution, are tentatively referred to *M. pacificus* on the basis of their subpentagonal outline and somewhat flattened margins.

A specimen from Loc. 124 (LAM), 15 feet below the floor level of Snyder Continuation School in San Diego, is 35 mm. in diameter. It is imperfectly preserved, but the general outline of the apical system is that of the present species. However, it may be referable to *M.* cf. *M. israelskyi* which occurs at that locality.

So far as is known, *Merriamaster pacificus* is restricted to the San Diego horizon or to beds of approximately that age in southern California and at Cedros Island, Lower California. The record cited by Argamakova[115] of the present species in the Nutovo series, late Pliocene, on Sakhalin Island, Russia, needs confirmation.

Family **MELLITIDAE** Stefanini

Medium-sized to large, flattened; well-developed internal supports; posterior interambulacral and paired ambulacral lunules or indentations; petals well defined, moderately closed; pores conjugate, outer member of pore-pair elongated, a few primary pore-pairs outside petals; paired interambulacra not in contact with basicoronal plates on oral surface; interambulacra on oral surface widening toward ambitus, about as wide as ambulacra at ambitus; basicoronal plates fairly small, interambulacral plates slightly larger than ambulacral plates; periproct on oral surface between posterior interambulacral lunule and peristome; ambulacral food grooves bifurcating just outside basicoronal plates. (Durham, 1955.) Early Miocene to Recent. Recent along tropical and warm temperate coasts of the Americas.

REMARKS: Two genera, *Encope* L. Agassiz and *Mellita* L. Agassiz, in this family, with 5 marginal lunules or notches, are known from the late Tertiary of California. *Scutaster* Pack, with 3 lunules, formerly included in this family, was recently placed in the family *Scutasteridae* by Durham, 1955.

Genus **ENCOPE** L. Agassiz

Encope L. Agassiz, Cat. Ectyp. Echin., pp. 6, 17, 1840. Sole species: "*grandis* Ag. . . . (Species viva.) Martinique."—L. Agassiz, Monogr. Echin. Viv. Foss., Seconde Monogr. Scutel., p. 45, 1841.—C. W. Cooke, Jour. Paleo., Vol. 16, No. 1, p. 19, 1942. "Genotype, *Encope grandis* Agassiz."—Mortensen, Monogr. Echin., IV.2. Clypeastroida, p. 433, 1948. "Genotype: *Encope grandis* L. Agassiz."—Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 42, 1950." Genotype: *Encope grandis* Agassiz (monotypic)"—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, p. 174, November 21, 1955. "Type species: of *Encope, E. grandis* L. Agassiz, monotypic."

Moulinia L. Agassiz, Monogr. Echin., Seconde Monogr. Scutel., pp. 3, 139, 1841. Sole species: "*Moulinia cassidulina* Ag.", pl. 22, figs. 1-6, 1841. From "côtes de la Martinique." [According to A. Agassiz, Mem. Mus. Comp. Zool., Vol. 3, pp. 326-328, 1872, and Mortensen, 1948, p. 435, this is "only a developmental stage of *Encope* (*emarginata*)"].

Moulinsia L. Agassiz in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 7, p. 139, 1847. For *Moulinia* L. Agassiz, 1841.

Echinoglyphus Van Phelsum, Gray, Proc. Zool. Soc. London for 1851, p. 37, October 28, 1852. "The *Encope* of Agassiz."

Echinoglycus Van Phelsum, Gray, Cat. Rec. Echin. Brit. Mus., Pt. 1, p. 24, 1855. Several species cited, including *Encope grandis* L. Agassiz.

Not *Echinoglycus* Van Phelsum, L. Agassiz, 1841. Type (designated by Durham, 1955, p. 175): *Echinoglycus irregularis* Leske [=*Echinodiscus bisperforatus* Leske.]

Ravenellia Lütken, Vidensk. Meddel. Nat. For. Kjobenhavn for 1863, p. 168 (100), 1863. Type by monotypy: *Scutella macrophora* Ravenel.

Not *Ravenelia* McCrady, 1859.

Macrophora Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, No. 2, p. 74, 1865. Species cited: "*M. macrophora*, (*Scutella*), Ravenel" and "*M. raveneli*, C." [*Scutella macrophora* Ravenel, type by tautonymy. Described in Proc. Acad. Nat. Sci. Philadelphia, Vol. 1, p. 81, 1841. "found in calcareous deposite upon my plantation on Cooper River, in St. Thomas's Parish, about 17 miles from Charleston." South Carolina. Pliocene.]

Desmoulinaster Lambert and Thiéry, Essai Nomencl. raisonnée Echin., Fasc. 4, p. 294, March, 1914. New name for *Moulinia* L. Agassiz, 1841 "(barbarisme)" and *Moulinsia* L. Agassiz, 1847, (not *Moulinsia* Grateloup, 1840). "Type unique: *D. cassidulinus* Desmoulins (*Scutella*)"...

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(115) Argamakova, V. F., Trans. Oil Geol. Inst., Ser. A, Fasc. 41, pp. 27, 41, pl. 1, fig. 6, 1934. On the right side of Great-Uini River, Sakhalin Island, Russia. Nutovo series, late Pliocene.

TYPE SPECIES (by monotypy): "*grandis* Ag. . . . (Species viva.) Martinique." [Described by L. Agassiz, Monogr. Echin., Seconde Monogr. Scutel., p. 57, pl. 6, figs. 1-9, 1841. ". . . provient probablement des Antilles." —A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol 3), Pt. 1, p. 127, 1872; Pt. 3, p. 545, pl. 13d, figs. 5, 6, 1873. Gulf of California. —Mortensen, Monogr. Echin. IV.2. Clypeastroida, p. 437, pl. 63, figs. 1, 2, 1948.]

RANGE: Early Miocene to Recent. Recent in tropical and subtropical waters on the east and west coasts of the Americas, from the intertidal zone to about 130 meters (71 fathoms), but usually in less than 50 meters (27 fathoms).

DESCRIPTION: Test stout, with a posterior interambulacral lunule, and with marginal notches or slits or lunules in two or more of the ambulacra; genital pores 5. (H. L. Clark, 1925.)

REMARKS: This genus is known to occur both living and fossil on the east and west coasts of the Americas. Durham (1950) recorded 13 species and subspecies from Pliocene and Pleistocene strata in the Gulf of California region. It is known to occur in Pleistocene beds at Magdalena Bay, Lower California. The present record of *Encope* in beds of Pliocene age at San Diego is the first record of its occurrence in late Tertiary strata of the coastal region of California. The occurrence of *Encope* has been known for years in the Pliocene beds in Imperial County, California, near the head of the Gulf of California.

Several species and subspecies have been described by A. H. Clark (1946) and H. L. Clark (1948) as occurring in tropical and subtropical waters of the western Americas, abundantly in the Gulf of California and south to northern Peru; but Mortensen (1948) recognized only 8 of these as valid. Dimensions of a large specimen of the genus *Encope* taken at the Galapagos Islands are given by H. L. Clark (1948) as 150 and 155 mm.

Mellita L. Agassiz, which has 4 rather than 5 genital pores, has already been recorded by the present authors (1938, pp. 101-103) from the Temblor beds of middle Miocene age in California and from Pleistocene sediment at San Diego and Newport Beach. J. P. Smith (1919, p. 131) also cited the occurrence of this genus in the Quaternary of southern California, as have several authors subsequently.

Encope tenuis Kew

Plate 23, Figures 7, 13; Plate 24, Figure 11; Plate 25, Figure 4

Encope tenuis Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 8, No. 5, p. 47, pl. 1, fig. 1; pl. 2, fig. 1, April 16, 1914.—Kew, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 12, No. 2, p. 136, pl. 36, fig. 1; pl. 37, figs. 1a, 1b, September 28, 1920. "Coyote Mountain, Imperial County, California." "Lower Division of the Carrizo Creek beds, Pliocene."

TYPE SPECIMEN: "Cotypes" Numbers 10050 and 10051, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "Lower Division of the Carrizo formation at Coyote Mountain and Carrizo Valley," California. "Pliocene." [Coyote Mountain, only, cited by Kew, 1920.]

RANGE: Middle Pliocene in southern California and in Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 107, 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego. SAN DIEGO SOCIETY OF NATURAL HISTORY: 31st Street and Logan Avenue in San Diego.

ORIGINAL DESCRIPTION: Test broad, transverse diameter sometimes greater than the antero-posterior diameter. Greatest width posterior to the center. Test thin, with sharply angular margin. Summit posterior to apical system and immediately anterior to interambulacral lunule or foramen. Area immediately surrounding the lunule somewhat tumid. Ambulacral notches broad, deep, contracting slightly near the margin of the test and tending to close. Both interambulacral lunule and ambulacral notches varying somewhat in size. Apical system central. Petals nearly closed, and reaching about two-thirds the distance to the margin. Petals rather narrow. The two lateral petals of the trivium broader and averaging nine per cent shorter than the others. Interporiferous areas slightly lenticular, and at widest part about same dimensions as the poriferous area. Actinal side flat, and marked by deep ambulacral furrows which branch immediately from the peristome and a second time a short distance from the outer margin. The main furrows are broad, shallow and straight, deepening

as the ambulacral notches are approached. Mouth small and not sunken. Anus situated on the inferior surface slightly anterior to the interambulacral lunule. (Kew.)

Measurements of figured specimens: of No. 10050, anteroposterior diameter, 92.7 mm., transverse diameter, 96.0 mm., greatest thickness, 10.3 mm.; of No. 10051, anteroposterior diameter, 110.9 mm., transverse diameter, 105.8 mm. (Kew.)

REMARKS: Two specimens of this species are represented in collections from the San Diego formation. The larger and more nearly complete specimen was collected by George Kanakoff at Loc. 107 (LAM), at the end of Arroyo Drive, San Diego. It measures 104.5 mm. in anteroposterior diameter, 97 mm. in transverse diameter (incomplete), and 12 mm. in height. One specimen in the collection of the San Diego Society of Natural History was collected by Mrs. L. D. Bonnet, San Diego, at 31st Street and Logan Avenue in that city. This specimen is fairly well preserved, but the margins are mostly incomplete. It is approximately 74 mm. in anteroposterior diameter.

The specimen in the collections of the San Diego Society of Natural History has adhering to it some gray micaceous silty sandstone, typical of the San Diego formation. Adhering to the specimen collected by Kanakoff is a slight amount of yellowish-gray sediment similar to that at the end of Arroyo Drive. It appears, then, that there is no reason to doubt the occurrence of this species in the San Diego formation. This record is in harmony with that of *Lovenia hemphilli*, which also occurs in the San Diego formation and in Pliocene strata in the Gulf of California region.

We compared specimens from San Diego with several specimens from Pliocene beds at Loc. 680 (CAS), Alverson Canyon, Coyote Mountain, Imperial County, California, identified as *Encope tenuis* by Merle C. Israelsky: no essential differences are evident. The test of this species is known to be somewhat variable. The specimens from Imperial County vary in the shape of the interambulacral lunule and in the distance it extends anteriorly beyond the posterior ends of the bivium.

Characteristic of *Encope tenuis* are the very thin margins, the shape of the test, highest posteriorly, and the posterior position of the interambulacral lunule relative to the bivium. The very thin margins and the open ambulacral notches distinguish *Encope tenuis* from the Recent *E. californica* Verrill[116], in which the openings are usually in the form of closed lunules.

Smith[117] mentioned the occurrence of *E. tenuis* in the fauna of "Carrizo (Imperial Co., Calif., and Cerros Island, Lower California, lat. 33°N. —28°N.)." However, this record probably refers only to the occurrence of *E. tenuis* in Imperial County, which he indicated on another page (page 150). Beal[118] mentioned "*Encope* sp. aff. *E. tenuis*" from the Pliocene Salada formation, 1 kilometer north of Rancho Conejo in the La Paz Quadrangle in south central Lower California.

Encope loretoensis Durham[119], described from Pliocene beds at Arroyo de Gua on the east coast of Lower California, was said to differ from *E. tenuis* in that about two-thirds of the interambulacral lunule extends anterior to a line connecting the ends of the bivium. In *E. tenuis*, as mentioned above, the anterior extent of the lunule is quite variable. In view of the variation it appears doubtful whether *E. loretoensis* should be assigned more than subspecific status.

Encope tenuis, *E. loretoensis*, and *E. californica* are members of a group which apparently is represented in the Caribbean by such forms as *E. michelini* L. Agassiz and *E. emarginata* Leske.

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(116) *Encope californica* Verrill, Amer. Jour. Sci., Ser. 2, Vol. 49, p. 97, January, 1870. "La Paz" and "Cape St. Lucas" in the "Gulf of California." Recent.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 96, pl. 11, fig. 4; pl. 30, fig. 2, 1938. Pleistocene and Recent.

(117) Smith, J. P., Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 149, 154, 1919.

(118) Beal, C. H., "Reconnaissance of the Geology and Oil Possibilities of Baja California, Mexico," Geol. Soc. Amer., Mem. 31, p. 81, 1948.

(119) *Encope loretoensis* Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 46, pl. 37, fig. 4; pl. 41, figs. 1, 4, 5, August 10, 1950. Loc. A-3552 (UC), an echinoid-pecten bed just above Loc. A 3551, which is, "Lower Pliocene, Arroyo de Gua, north of Loreto, Lower California. On north side of arroyo, about a quarter of a mile below point where road passes over divide into Arroyo de Arce. A 2-foot zone of echinoids interbedded in sandstones and conglomerates."

Order **SPATANGOIDA** Claus

Family **SPATANGIDAE** Gray

Peristome transversely elongated; some or all of the ambulacra more or less petaloid, or more or less sunken, or both; subanal fasciole present. (H. L. Clark, 1925.) Paleogene to Recent. (Durham and Melville.)

Genus **SPATANGUS** Gray

Spatagus O. F. Müller, Prod. Zool. Danicae, p. 236, 1776. Species listed: *S. purpureus* [Müller] and *S. pusillus* [Müller].

Spatangus Klein, Gray, Ann. Philos., Vol. 26, p. 430, 1825. Sole species: "*S. purpureus*, Leske, t.43, f.3,5; t.45,f.5."—Mortensen, Monogr. Echin. V.2. Spatangoida, II, p. 6, December 20, 1951. "Genotype: *Spatangus purpureus* O. Fr. Müller."

Not *Spatangus* Klein, Nat. Dispositio Echin. p. 33, 1734 (pre-Linnaean).

Prospatangus Lambert, Mém. Soc. Géol. France, Paléon., Vol. 9, Fasc. 3, Mém. 24, p. 55, 1902.—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 6, 7, p. 459, December, 1924. "Type: *P. purpureus* Müller (*Spatangus*), vivant des mers d'Europe."

Spatangus O. F. Müller, H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 233, 1917. "Type, *Spatangus purpureus* O. F. Müller, 1776."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 131, 1938. "Type of the genus (designated by H. L. Clark, . . . 1917): *Spatangus purpureus* O. F. Müller."

TYPE SPECIES (designated by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, p. 233, 1917, "Type, *Spatangus purpureus* O. F. Müller, 1776"; and *Spatangus* Gray with the type species, *Spatagus purpureus* O. F. Müller, placed on the Official List of Generic Names in Zoology in Opinion 209 of the International Commission on Zoological Nomenclature, March 8, 1954): *Spatagus purpureus* O. F. Müller [Prod. Zool. Dan., p. 236, 1776. Denmark and adjacent regions. Figured by A. Agassiz, Illustr. Cat. Mus. Comp. Zool. No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 3, p. 565, pl. 11f, figs. 19-22; pl. 14a, fig. 1; pl. 19c, figs. 5, 6; pl. 26, figs. 24-27; pl. 32, figs. 17, 18; pl. 34, figs. 3, 4; pl. 37, fig. 16; pl. 38, figs. 34, 35, 1873. "Norway; Mediterranean." —Mortensen, Danish Ingolf-Exped., Vol. 4, Pt. 2, Echin. (2), pp. 123-129, pl. 2, figs. 8, 12, 14, 16; pl. 16, figs. 1-2, 5-10, 22, 24-25, 27, 29, 31-32, 34, 1907. North Sea, Faroe Island, etc. See also Mortensen, 1951, pp. 10-14, for synonymy and discussion of this species.]

RANGE: Eocene to Recent. Bathymetric range of Recent species usually from 50 to 1000 meters (27 to 547 fathoms), one species (*S. raschi* Lovén) to a depth of 1472 meters (805 fathoms).

DESCRIPTION: Peripetalous fasciole wanting; sternum well developed, much longer than wide, fully covered with tubercles; at least ten distal pore-pairs developed in anterior series of Petals II and IV: genital pores four. (H. L. Clark, 1925.)

REMARKS: In the eastern Pacific this genus, with heart-shaped test, occurs chiefly in shallow waters of the northern hemisphere; but in the eastern Atlantic it ranges south to the Cape of Good Hope and in the south Pacific to New Zealand, occasionally to a depth of 1472 meters (805 fathoms). Ten Recent species were included in this genus by Mortensen. The only Recent species of western North America, *Spatangus californicus* H. L. Clark, occurs from Cordell Bank, California, to San Francisquito Bay in the Gulf of California at depths ranging from 64 to 412 meters (35 to 225 fathoms). Three species of this genus have been described from the Tertiary of California, *Spatangus pachecoensis* Pack and *S. tapinus* Schenck from strata of Eocene age and *S. rarus* Israelsky from strata of Pliocene age.

Spatangus rarus Israelsky

Plate 25, Figures 1-3

Spatangus rarus Israelsky, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 11, p. 383, pl. 73, figs. 1a-1c, November 7, 1923.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 132, pl. 10, fig. 6, 1938. "Pliocene. —Pacific Beach, San Diego, California (Israelsky)."

TYPE SPECIMEN: Holotype No. 917, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Pacific Beach, San Diego, California." "Pliocene."

RANGE: Known only from the type locality.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 547, Pacific Beach (Israelsky; Grant and Hertlein). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20-30 feet below the end of Loring Street, Pacific Beach.

ORIGINAL DESCRIPTION: Marginal outline of the test nearly circular, notched anteriorly, shallowly truncated posteriorly. Abactinal surface somewhat elevated, gently arched, greatest height of test

anterior to the apical system which is subcentral. Petals paired, slightly sunken below general surface of test; pores paired, about 1 mm. apart and zygose. Odd anterior ambulacrum non-petaloid, lying wholly in groove which extends from ambitus to the apical system. Antero-lateral ambulacra petaloid, with petal outlines somewhat convex to the anterior and being nearly straight lines posteriorly; petals terminated about two-thirds the distance from the apex to the ambitus; ambulacra widen rapidly below petals. Posterior ambulacra petaloid, somewhat longer than the anterior, both poriferous areas concave toward a medial line; petals reach three-fifths of distance to ambitus from apex. Peristome anterior. Periproct with major diameter transverse (width 12 mm., height 6 mm.), elliptical in outline and lying close to upper edge of posterior truncation. Large tubercles scrobiculate, occurring only in interambulacral areas; most numerous in anterior interambulacral areas in the anterior portions; five primary tubercles in the anterior row of plates of the posterior paired interambulacrals; only one in the posterior plate row of the same areas; several also occur along the crest of the ridge in the posterior interambulacrum. Granules found over the whole of test. Measurements: Length, 72.5 mm.; width, 77.0 mm.; height, 29.3 mm. (Israelsky.)

REMARKS: In addition to the type specimen of *Spatangus rarus*, we have examined two imperfect specimens, the larger 82 mm. in length, from Loc. 122 (LAM), Pacific Beach, San Diego; but these add no new information concerning this species.

Israelsky mentioned that this species more closely resembles some of the species from the late Tertiary of Europe, especially *Spatangus corsicus* Desor[120] than it does the Recent west American *S. californicus* H. L. Clark[121].

A form from the Miocene of western Ukraine described by Szörényi[122] has wide ambulacral petals reminiscent of *Spatangus rarus;* but it differs somewhat in shape, and the apical system appears to be more anteriorly placed.

Family **LOVENIIDAE** Lambert, emended Mortensen

Differs from all other Spatangoids by the presence of an "inner" or "internal" fasciole, surrounding only the frontal ambulacrum and the apical system. (Mortensen, 1951.) Paleogene to Recent. (Durham and Melville.)

Genus **LOVENIA** Desor

Lovenia Desor in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 6, pl. 16, fig. 16; Vol. 8, pp. 10, 11, July, 1847. —H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 251, 1917. "Type, *Lovenia hystrix* Agassiz and Desor, 1847 =*Spatangus elongatus* Gray, 1845, Eyre, Voy. 1, p. 436."—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 6 & 7, p. 466, 1924. "Type: *L. elongata* Gray (*Spatangus*) vivant de l'Océan Indien, dont *L. hystrix* Desor est un simple synonyme."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 135, 1938. "Type of the genus (by monotypy): *Lovenia 'Hystrix* Desor' . . . =*Spatangus elongatus* Gray."—Mortensen, Monogr. Echin. V.2. Spatangoida.II, p. 89, December 20, 1951. "Genotype: *Lovenia elongata* (Gray)."

TYPE SPECIES (by monotypy): "*Hystrix* Desor. —Descript. Egypt. Zool., Pl. 7, fig. 4," in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 8, p. 11, pl. 16 (Vol. 6), fig. 16, 1847. "Mer Rouge (Botta). —Mus. Paris." [= *Spatangus elongatus* Gray in E. J. Eyre, Jour. Centr. Austral., Vol. 1, p. 436, pl. 6, fig. 2, 1845. Australia. Illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 139, 1872; Pt. 3, p. 575, pl. 19c, figs. 1-4; pl. 25, fig. 31; pl. 26, figs. 35, 36; pl. 37, figs. 17, 18; pl. 38, figs. 27, 28, 1873. "Red Sea: Australia; Philippine Islands." Also Zanzibar. —Mortensen, 1951, p. 97, figs. 48a, 49, 50, 51, 52a;

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(120) *Spatangus corsicus* Desor in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 8, p. 7, July, 1847. "Tert. de Balestro (Corse), Saint-Paul-Trois-Châteaux (Drôme)." Figured by Loriol, Direction des Travaux Géologiques du Portugal. Description des Echinodermes Tertiaires du Portugal, pp. 47-48, pl. 13, figs. 3, 3a, 3b, 1896. "Bassin du Tage." Also "Santa Manza, Balistro, (Corse). (Helvétien).—Sardaigne. (Langhien)."

(121) *Spatangus californicus* H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 235, pl. 146, fig. 20; pl. 149, fig. 4; pl. 156, figs. 1-3; pl. 157, fig. 10, March, 1917. "Off southern California." "68 fms." Bathymetric range, 45-73 fathoms. Extremes of temperature, 56.5°-42.4°F.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 132, pl. 10, fig. 5; pl. 30, fig. 5, 1938. Off southern California to Cedros Island, Lower California. It also occurs at least as far north as Cordell Bank in central California. See also Mortensen (1951, p. 16, pl. 2, figs. 1, 2).

This species was cited erroneously as *Spatangus pacificus* by Israelsky (1923, p. 383).

(122) *Prospatangus* n. sp., Szörényi, Geol. Hungarica, Ser. Palaeo., Fasc. 23, p. 91, pl. 7, fig. 6, 1953. "Grabnik," western Ukraine. Miocene.

pl. 7, figs. 1-10; pl. 8, fig. 1; pl. 12, fig. 5; pl. 47, figs. 10-23. Indo-Pacific. See also H. L. Clark, Carnegie Inst. Washington, Publ. 566, p. 381, 1946. North Australia, South Africa, and Aden to Misaki, Japan.]

RANGE: Miocene to Recent. Cosmopolitan. Bathymetric range, in west American waters (*L. cordiformis*), usually from ebb tide to 137 meters (75 fathoms); one species in the Indo-Pacific (*L. gregalis* Alcock) occurs to a depth of 930 meters (509 fathoms) according to Mortensen (1951, p. 123).

DESCRIPTION: An internal fasciole present but no peripetalous; large, deeply sunken primary tubercles present in interambulacra on both upper and lower surfaces; sternum with tubercles confined to posterior part; petals I and V well formed. (H. L. Clark, 1925.)

REMARKS: *Pseudolovenia* A. Agassiz and H. L. Clark[123] is believed to be closely related to *Lovenia,* but it differs in that petals I and V are not at all petaloid and that the anterior petals are longer and narrower.

Only two species of *Lovenia* have been described from western North America: *L. hemphilli* Israelsky from Pliocene strata at San Diego, and *L. cordiformis* A. Agassiz, a Recent species described from Guaymas and the Gulf of California, ranging from Point Conception, California, to Panama, from the intertidal zone to a depth of 137 meters (75 fathoms). Mortensen recognized nine species and one variety of *Lovenia* as now living. The genus has not been reported from the Atlantic Ocean, but it is represented by fossil forms in late Tertiary strata in that region.

Lovenia hemphilli Israelsky

Plate 24, Figures 1-3, 18

Lovenia hemphilli Israelsky, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 11, p. 384, pl. 74, figs. 1a-1c, 2, November 7, 1923. "Pacific Beach, San Diego Co., California," Pliocene.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 137, pl. 13, figs. 3, 4, 1938. "Pacific Beach, San Diego"; "near Market Street and Euclid Avenue, San Diego."—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 57, 1944. "Pacific Beach."—Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 51, pl. 44, figs. 2, 6 (Monserrate Island, Pliocene), 3, 4 (San Diego Pliocene), 1950. "San Diego Pliocene."—Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1954 (1955). "San Diego formation."

TYPE SPECIMEN: "Cotypes" [Syntypes] Nos. 918 and 919, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Pacific Beach, San Diego Co., California." "Pliocene, San Diego formation." In "Micaceous sandstone."

RANGE: Middle Pliocene in southern California and at Monserrate Island, Gulf of California.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 547, Pacific Beach (Israelsky; Grant and Hertlein); Loc. 1399, road cut 0.1 mile east of Euclid Avenue on Market Street; Loc. 1413, lower beds in Pliocene section at Pacific Beach; Loc. 1414, middle beds in Pliocene section at Pacific Beach. LOS ANGELES COUNTY MUSEUM: (?)Loc. 107, 100-foot bluff, with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach.

ORIGINAL DESCRIPTION: Outline of test from above slightly cordiform, notched anteriorly, narrowed, and shallowly truncated posteriorly, greatest width slightly anterior to the apical system; greatest height posterior to apical system about two-thirds of distance from that system to the posterior truncation in the odd interambulacral area which is somewhat ridged. Apical system forward of center of test. Anterior odd ambulacrum in groove which reaches from the ambitus nearly to the apex. Antero-lateral petals sub-triangular, pointed anteriorly, slightly depressed, aborted by internal fasciole near the apical system, with anterior pore rows approximating a straight line transverse to the major diameter of the test; petals reach two-thirds of distance to ambitus. Postero-lateral petals nearly twice as long as the anterior, more lanceolate in outline, posterior pore rows forming an angle of about 80 one with the other. Pores in petals large, zygose. Primary tubercles present in all interambulacra excepting the odd posterior, the number varying with the individual (age factor); deeply scrobiculate, reflected internally by overlapping rings; primaries not found on ambital area. Miliaries found over

(123) *Pseudolovenia* A. Agassiz and H. L. Clark, Bull. Mus. Comp. Zool., Vol. 50, No. 8, p. 255, March, 1907. Type (by monotypy): *Pseudolovenia hirsuta* A. Agassiz and H. L. Clark. Several localities off the Hawaiian Islands in 192-692 fathoms. Figured by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, pp. 258-261, pl. 146, figs. 32, 33; pl. 160, figs. 8-12, 1917. Hawaiian Islands and Japan.

entire test. Peristome anterior to center of actinal side. Periproct posterior, lying in upper portion of deeply sunken depression which obliquely truncates the test at rear. (Israelsky.)

Measurements [Israelsky]:	Cotype No. 918, CAS	Cotype No. 919, CAS
Length	75.0 mm.	79.5 mm.
Width	63.1 mm.	67.3 mm.
Height	19.9 mm.	20.5 mm.

REMARKS: Eight specimens of this species in various states of preservation were collected by George P. Kanakoff and J. F. Arndt at Loc. 122 (LAM), Pacific Beach. These vary in length from 74.6 mm. to 82 mm. and in width from 56 mm. to 62 mm. In addition to these and the syntypes, we have studied a few other specimens, mostly incomplete ones, from Pacific Beach and from other localities. The exposed portions of all the specimens available to us from the San Diego area reveal the characteristic features of the syntypes.

Lovenia hemphilli differs from the Recent west American *L. cordiformis* A. Agassiz[124] in that the test is lower in proportion to the length and that the posterior truncation is sloping rather than nearly vertical. *Lovenia cordiformis* ranges[125] from Point Concepcion, California, to Panama and the Galapagos Islands, from shore to a depth of 137 meters (75 fathoms). Mortensen (1951, p. 108) thought that either *L. hemphilli* or *L. dumblei* Dickerson and Kew[126] might be the ancestor of *L. cordiformis*.

Israelsky pointed out the resemblance of *L. hemphilli* to *L. elongata* Gray (= *L. hystrix*, type species of *Lovenia*), but it differs in the character of the petals. He also called attention to the striking resemblance of *L. hemphilli* to *Sarsella duncani* Gregory[127], described from Oligocene Globigerina limestone of Malta.

L. hemphilli resembles members of the *L. elongata* group, which includes *L. camarota* H. L. Clark[128], *L. elongata* Gray, *L. cordiformis* A. Agassiz, and *L. hawaiiensis* Mortensen. *Lovenia similis* H. L. Clark[129], from Miocene strata in Fiji, may be another member of this group; but Mortensen expressed doubt that it is referable to the genus *Lovenia*. He suggested that it might belong to the genus *Breynia* Desor.

Family **SCHIZASTERIDAE** Lambert

The main character of this family is the presence (excepting *Amphipneustes*) of both a peripetalous and a latero-anal fasciole. (Mortensen, 1951.) Late Cretaceous to Recent.

Genus **BRISASTER** Gray

Brisaster Gray, Cat. Rec. Echin. Brit. Mus., p. 61, 1855. Species cited: *Schizaster fragilis* Düben and Koren (*Brissus fragilis* Düben and Koren), "Hab. Shores of Finmark"; *Schizaster gibberulus* Agassiz and Desor, "Hab. Red Sea"; *Schizaster cubensis* d'Orbigny, "Hab. Cuba, D'Orbigny".—H. L. Clark, Cat. Rec. Sea-Urchins Brit. Mus., p. 206, 1925. "Type, *Brissus fragilis* Düben and Koren".—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 122, April 19, 1938. Type as in preceding reference.—Mortensen, Monogr. Echin., V.2. Spatangoida. II, p. 280, December 20, 1951. "Genotype: *Brisaster fragilis* (Düben & Koren)."

Lymanaster Lambert in Castex and Lambert, Actes Soc. Linn. Bordeaux, Vol. 71, p. 52, 1920. Type: *Brisaster townsendi* A. Agassiz.

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(124) *Lovenia cordiformis* A. Agassiz, Bull. Mus. Comp. Zool., Vol. 3, No. 4, p. 57, 1872. "Mus. Comp. Zoöl. Guayamas; Smith. Coll. Gulf of California." Footnote states "Lütken MS. in litt."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 136, pl. 11, figs. 2, 3; pl. 13, figs. 1, 2, 1938. Pleistocene and Recent. [Mortensen (1951, V.2, p. 107) considered Lütken to be the author of this species and Guayaquil, Ecuador, to be the type locality.]

(125) *Lovenia cordiformis* was recorded from the Hawaiian Islands by Ziesenhenne (1937, p. 236) and by H. L. Clark. Mortensen doubted the Hawaiian occurrences, believing that those records may be referable to *L. hawaiiensis* Mortensen (see Mortensen 1951, p. 107, pl. 13, figs. 24-30; pl. 48, figs. 2, 6, 7).

(126) *Lovenia dumblei* Dickerson and Kew, Proc. Calif. Acad. Sci., Ser. 4, Vol. 7, p. 136, pl. 17, figs. 2a-2c, July 30, 1917. Type locality, "Nuevo Rancho, 35 kilometers northwest of Tuxpan, near Cerro Azul," Mexico. "Upper Oligocene or Miocene."

(127) *Sarsella duncani* Gregory, Trans. Roy. Soc. Edinburgh, Vol. 36, Pt. 3, p. 624, 1890-1891 (May 10, 1892). Ref. to *Spatangus ocellatus* Defrance of T. Wright (*non* Defrance, 1827), Quart. Jour. Geol. Soc. London, Vol. 20, pp. 487-488, pl. 21, figs. 1a, 1b, 1864.

(128) *Lovenia camarota* H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 253, pl. 161, figs. 1-4, March, 1917 . . . . "west of Torres Strait, 28 fms., mud."

(129) *Lovenia similis* H. L. Clark, Bernice P. Bishop Mus., Bull. 181, p. 327, pl. 43, fig. G, January, 1945. "Oneata," Island of Lau group, Fiji, probably late Miocene.

TYPE SPECIES (designated by Lambert, Mém. Soc. Geol. France, Paléo., Tom. 14, Fasc. 2-3 (Mém. No. 24) p. 112, 1906): *Brisaster fragilis* Düben and Koren [= *Brissus fragilis* Düben and Koren, Kgl. Vetensk. Akad. Handl., p. 280, Tab. 10, figs. 47-49, 1844. Illustrated by Mortensen, 1951, pl. 23, figs. 1, 16-19. (Synon. pp. 283-284). Barents Sea, Murman coast and North Atlantic to Bergen, Norway, and Iceland and from Lat. 66°N. to Florida in west Atlantic, in 40 to 1300 meters.]

RANGE: Eocene to Recent (Lambert and Thiéry, 1925). [According to Mortensen, many of the species referred to *Brisaster* by Lambert and Thiéry are not referable to that genus.] Recent in North Atlantic, South Atlantic, eastern Pacific, and Japan, in 35 to 1900 meters (19 to 1039 fathoms).

DESCRIPTION: Test low, apex posterior; genital pores 3; posterior petals relatively short; petals II and IV at first little divergent, then becoming more so, and at tip markedly curved outward. (H. L. Clark, 1925.)

REMARKS: *Brisaster* is represented in the Oligocene of Oregon by *B. maximus* H. L. Clark, and in the Pliocene of California by *Brisaster* cf. *B. townsendi* A. Agassiz, by a subspecies described here as *B. townsendi woynari,* and perhaps by *"Schizaster (?)" stalderi* Weaver.

Seven species of this genus are recorded by Mortensen as occurring in the seas at the present time.

The test of *Faorina* Gray, which also possesses 3 genital pores, has the apical system nearly central, and the peripetalous fasciole is double anteriorly.

Brisaster townsendi woynari Hertlein and Grant, new subspecies

Plate 25, Figure 5; Plate 26, Figures 1-3

DESCRIPTION: Test is similar to that of *Brisaster townsendi* A. Agassiz in general features. The apex is about two-fifths of the distance from the posterior end, and the petals of the bivium, angle about 100°, are a little more than one-half the length of petals II and IV. The subspecies differs from typical *B. townsendi* in the greater size and more nearly quadrate outline of the test and in the more nearly central position of the apical system. Spines on the plastron are about 8 mm. in length. The test may be slightly crushed as a result of the compaction of the sediment, but the specimens available are comparatively uniform in outline. Dimensions are as follows: holotype, length 91.5 mm., width 90 mm., height 34.5 mm.; paratype, length 90 mm., width 92 mm., height 35.5 mm.; paratype, length 92 mm., width 91.8 mm., height 35.5 mm.

Two large specimens, slightly crushed and partly covered with concretionary material, have the following measurements: the larger one, length 97 mm., width 101 mm., height 33 mm.; the other one, length 94 mm., width 91 mm., height 32.5 mm.

TYPE SPECIMENS: Holotype and Paratypes, Invertebrate Paleontology Collection, Los Angeles County Museum.

TYPE LOCALITY: Loc. 107 (LAM), 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; C. W. Woynar, coll.; San Diego formation, Pliocene.

RANGE: Known only from the type locality.

REMARKS: Portions of the specimens of this new subspecies are covered with a very hard matrix of sandstone, but most of the shell characters are revealed. The angle of the bivium is about 100°, whereas in the Recent *Brisaster townsendi* A. Agassiz[130] the angle is about 105 to 110°. This apparent difference may not be significant, for Mortensen has pointed out that anomalies in the form of the bivium occur in Recent specimens of *B. townsendi.* However, taken as a whole, the characters enumerated in the description of the present fossil form appear to differ from those of the Recent species sufficiently to justify its status as a distinct subspecies.

(130) *Schizaster townsendi* A. Agassiz, Bull. Mus. Comp. Zool., Vol. 32, No. 5, p. 82, June, 1898. Gulf of Panama, 146-995 fathoms and 50 miles south of Guaymas, Mexico, in 628 fathoms.

Brisaster townsendi A. Agassiz, Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 123, pl. 1, fig. 6; pl. 14, figs. 1-3, 1938. Earlier records cited; also various records from western North America. Pliocene to Recent. —H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 340, pl. 64, fig. 64, 1948. Southeastern Alaska to the Galapagos Islands in 20 to 995 fathoms.—Mortensen, Monogr. Echin., V.2. Spatangoida. II, p. 288, pl. 24, figs. 1, 2, 9-19; pl. 53, figs. 21-27, 1951. Southeastern Alaska to Panama, 35-1900 meters.

An imperfectly preserved specimen of a *Brisaster* approximately 55.5 mm. long and 52.6 mm. wide, in the collections of the San Diego Society of Natural History, was collected by W. E. Pennington at Pacific Beach. The anterior portion of the aboral surface of the specimen, bearing a peripetalous fasciole, agrees with that of the present subspecies and likewise is similar to that of Recent specimens of *Brisaster townsendi* of comparable size except that ambulacrum III is narrower. This latter feature might be due to compaction of the sediment.

A fragment of a sea-biscuit, 46 mm. long, from Loc. 122 (LAM), Pacific Beach, appears to be referable to the genus *Brisaster*. It may, perhaps, represent a young specimen of the new subspecies described above.

The largest specimen of Recent *Brisaster townsendi* A. Agassiz that we have seen is one measuring 70 mm. in length from Loc. 24834 (CAS), off Bainbridge Island, Washington, in 219 meters (120 fathoms). Mortensen (1951, p. 289) mentioned a specimen 77 mm. in length. According to the same author, the type species of the genus, *B. fragilis*, attains a length of 90 mm. A series of specimens of *B. townsendi* shows considerable variation in the degree of flatness of the abactinal surface.

The present authors (1938, p. 123) recorded a specimen under the name of "*Brisaster* cf. *townsendi*" from strata of Pliocene age from a well in Orange County, California. Mortensen (1951, p. 282) suggested that the species described as *Schizaster* (?) *stalderi* by Weaver[131] from Pliocene beds in northern California is probably referable to the genus *Brisaster*. The only other species of this genus recorded as a fossil from western North America is *Brisaster maximus* H. L. Clark[132] (length about 84 mm., width approximately 76 mm.) from beds of Oligocene age in western Oregon.

Brisaster townsendi ranges from the Bering Sea to the Gulf of California and south to Panama, in 20 to 1900 meters (11 to 1039 fathoms). It is abundant off the coast of California in 91 to 146 meters (50 to 80 fathoms).

This new subspecies is named for Mr. William C. Woynar, San Diego, California, who collected the type specimens.

(131) *Schizaster* (?) *stalderi* Weaver, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 5, No. 17, p. 274, pl. 21, fig. 3, December 28, 1908. "Humboldt County, California, in beds presumed to represent the Wild Cat series of Lawson."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 121, pl. 25, fig. 6, 1938. Earlier records cited. Pliocene.

(132) *Brisaster maximus* H. L. Clark, Trans. San Diego Soc. Nat. Hist., Vol. 8, No. 28, p. 368, pl. 24, fig. 9, December 15, 1937.—Weaver, Univ. Washington Publ. Geol., Vol. 5, p. 11, pl. 4, fig. 5, issued December 31, 1943.

PLATES 19 TO 26

EXPLANATION OF PLATE 19

FIG. 1. *Astrangia* cf. *A. insignifica* Nomland. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian, southwestern San Diego County, California (see U.S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). Diameter of calice 4.3 mm. P. 79

FIG. 2. *Astrangia* cf. *A. insignifica* Nomland. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Diameter of calice 3.2 mm. P. 79

FIG. 3. *Astrangia* cf. *A. insignifica* Nomland. Side view of specimen shown in fig. 2.

FIG. 4. *Astrangia* cf. *A. insignifica* Nomland. Base of specimen shown in figs. 2 and 3.

FIG. 5. *Dendrophyllia* cf. *D. oldroydi* Faustino. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1, showing interior of calice. Length of specimen 19 mm. See also figs. 6 and 15. P. 82

FIG. 6. *Dendrophyllia* cf. *D. oldroydi* Faustino. Hypotype (Los Angeles County Museum); same specimen as shown in figs. 5 and 15, showing branching character. P. 82

FIG. 7. *Astrangia* cf. *A. insignifica* Nomland. Base of specimen shown in fig. 1.

FIG. 8. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Side view. Height 16.2 mm. P. 80

FIG. 9. *Paracyathus stearnsii* Verrill. Corallum of specimen shown in fig. 8. Greater diameter of calice 15 mm.; lesser diameter 11 mm. P. 80

FIG. 10. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height of specimen 9 mm.; greater diameter of calice 9 mm. P. 80

FIG. 11. *Paracyathus stearnsii* Verrill. Same specimen shown in fig. 10, showing character of budding.

FIG. 12. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Exterior of portion of corallum. Height of specimen 7.8 mm. P. 80

FIG. 13. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Greater diameter of calice approximately 11.3 mm.; lesser diameter 9.4 mm. P. 80

FIG. 14. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1, showing one individual attached to another. Height of specimen 10 mm. P. 84

FIG. 15. *Dendrophyllia* cf. *D. oldroydi* Faustino. Hypotype (Los Angeles County Museum); same specimen shown in figs. 5 and 6. Calice diameter 9.5 mm. P. 82

FIG. 16. *Terebratalia occidentalis* Dall. Hypotype (California Academy of Sciences), from Loc. 1419 (CAS), northeast corner of India and Thorn streets, San Diego, California. View of exterior of pedicle valve. Length 14.9 mm.; width 19.3 mm. P. 94

FIG. 17. *Glottidia albida* Hinds. Hypotype (University of California at Los Angeles), from Loc. L-309 (UCLA), southeast corner of India and Upas streets, San Diego, California. Length 12.5 mm.; width 8 mm. Interior of apical portion of pedicle valve, showing diverging laminae. P. 89

FIG. 18. *Glottidia albida* Hinds. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Length 12 mm.; width 5.5 mm. Exterior of dorsal valve. P. 89

FIG. 19. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height 21 mm.; maximum diameter 7 mm. P. 84

FIG. 20. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height 13.8 mm.; maximum diameter 7.3 mm. P. 84

FIG. 21. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height 15 mm.; maximum diameter approximately 7.5 mm. P. 84

FIG. 22. *Terebratalia occidentalis* Dall. Hypotype (California Academy of Sciences), from Loc. 28159 (CAS), Pacific Beach, San Diego, California. Length 16 mm.; width, incomplete, 20.4 mm. Exterior of dorsal valve. P. 94

FIG. 23. *Glottidia albida* Hinds. Hypotype (California Academy of Sciences), from Loc. 1401 (CAS), south slope of Soledad Mountain, San Diego, California. Length 9.3 mm.; width 5 mm. Exterior of dorsal valve. P. 89

FIG. 24. *Glottidia albida* Hinds. Hypotype (Los Angeles County Museum), 50 feet northeast of Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 19.9 mm.; width (one valve) approximately 7.8 mm. Exterior of dorsal valve. P. 89

FIG. 25. *Glottidia albida* Hinds. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 24. Length 21 mm.; width 10 mm. Exterior of pedicle valve. P. 89

FIG. 26. *Terebratalia hemphilli* Dall. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), Pacific Beach, San Diego, California. Length 38.9 mm.; width (incomplete) 38 mm. Exterior of pedicle valve. P. 93

FIG. 27. *Terebratalia hemphilli* Dall. Hypotype (California Academy of Sciences), from Loc. 547 (CAS), Pacific Beach, San Diego, California. Length 40.6 mm.; width (incomplete) 38 mm. Exterior of brachial valve. P. 93

FIG. 28. *Strongylocentrotus franciscanus* A. Agassiz. Hypotype (California Academy of Sciences), from Loc. 12163 (CAS), Pacific Beach, San Diego, California. Portion of a small test. Diameter 21.5 mm. P. 111

FIG. 29. *Strongylocentrotus purpuratus* Stimpson. Hypotype (Los Angeles County Museum), from Loc. 153 (LAM), Pacific Beach, San Diego, California. Portion of somewhat crushed test. Diameter 79.6 mm. P. 112

FIG. 30. *Terebratalia arnoldi* Hertlein and Grant. Hypotype (California Academy of Sciences), from Loc. 1399 (CAS), Pacific Beach, San Diego, California. Length 41 mm.; width 39.3 mm. Exterior of pedicle valve. P. 92

FIG. 31. *Terebratalia occidentalis* Dall. Hypotype (No. 7324, California Academy of Sciences), from Loc. 12007 (CAS), Pacific Beach, San Diego, California. Length 21 mm.; width 27.2 mm.; convexity of brachial valve 5.7mm. Exterior of brachial valve. P. 94

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EXPLANATION OF PLATE 20

FIG. 1. *Laqueus californianus* Koch. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 38 mm.; width 33.3 mm.; convexity (both valves together) 18 mm. Pedicle valve. P. 96

FIG. 2. *Laqueus californianus* Koch. Dorsal view of specimen shown in fig. 1.

FIG. 3. *Laqueus californianus* Koch. Side view of specimen shown in figs. 1 and 2.

FIG. 4. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 36.4 mm.; width 28 mm.; convexity (both valves together) 22.5 mm. Pedicle valve. P. 97

FIG. 5. *Laqueus californianus* Koch. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Length 38.2 mm.; width 29 mm.; convexity (both valves together) 18.2 mm. Dorsal view. P. 96

FIG. 6. *Laqueus californianus* Koch. Dorsal view of specimen shown in fig. 5.

FIG. 7. *Laqueus californianus* Koch. Side view of specimen shown in figs. 5 and 6.

FIG. 8. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 4.

FIG. 9. *Laqueus vancouveriensis diegensis* Hertlein and Grant new subspecies, Holotype (No. 7355, California Academy of Sciences), from Loc. 12005 (CAS), Pacific Beach, San Diego, California. Length 34.5 mm.; width 29.5 mm.; convexity (both valves together) 21.6 mm. Pedicle valve. P. 97

FIG. 10. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Holotype. Dorsal view of specimen shown in fig. 9.

FIG. 11. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Holotype. Side view of specimen shown in figs. 9 and 10.

FIG. 12. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Side view of specimen shown in figs. 4 and 8.

FIG. 13. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (No. 7354, California Academy of Sciences), from Loc. 537 (CAS), Pacific Beach, San Diego, California. Length 33.8 mm.; width 31 mm.; convexity (both valves together) 20.5 mm. Pedicle valve. P. 97

FIG. 14. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 13.

FIG. 15. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Side view of specimen shown in figs. 13 and 14.

FIG. 16. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (San Diego Society of Natural History), from Loc. 726 (SD), Pacific Beach, San Diego, California. Length 30.6 mm.; width 24 mm.; convexity (both valves together) 20.3 mm. Pedicle valve. P. 97

FIG. 17. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 16.

FIG. 18. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (Cat. No. 2420, University of California at Los Angeles), bluffs along Pacific Beach, about ½ mile southeast of False Point, La Jolla quadrangle, San Diego, California. Length 35.9 mm.; width 32.5 mm.; convexity (pedicle valve) 11.2 mm. Exterior of pedicle valve. P. 97

FIG. 19. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Interior of valve shown in fig. 18.

FIG. 20. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (University of California at Los Angeles), from same locality as specimen shown in figs. 18 and 19. Length 35 mm.; width 33 mm.; convexity (both valves together) 16.4 mm. Specimen slightly crushed. Pedicle valve. P. 97

FIG. 21. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 20.

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EXPLANATION OF PLATE 21

FIG. 1. *Dendraster ashleyi* Arnold. Hypotype (No. 6325, University of California at Los Angeles), from Quayle's Loc. 8, Las Chollas Valley, San Diego, California. Length 66 mm.; width 75 mm.; height approximately 11 mm. Aboral surface. P. 117

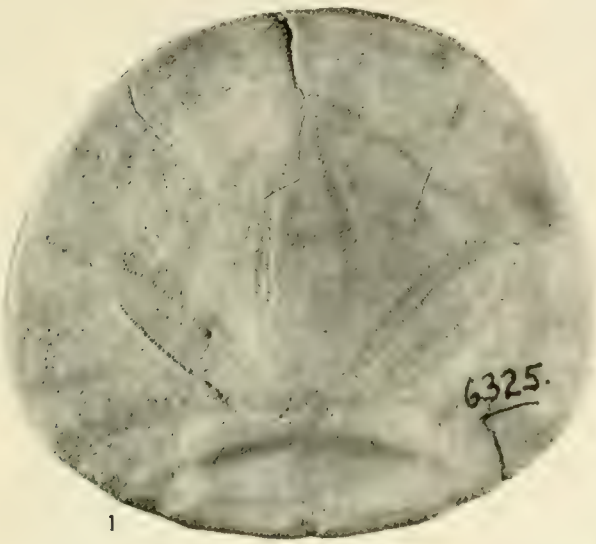
FIG. 2. *Dendraster ashleyi* Arnold. Hypotype (Los Angeles County Museum), from Loc. 306 (LAM), east side of Euclid Avenue between Federal Boulevard and intersection of Euclid and Home avenues, San Diego, California. Length 52.3 mm.; width 57 mm.; height approximately 8.5 mm. Oral surface. P. 117

FIG. 3. *Dendraster ashleyi* Arnold. Hypotype Cat. No. 3374, (University of California at Los Angeles), from Loc. 296 (UCLA), street cut on northwest side of Fairmount extension, 0.4 mile north of intersection with Broadway, on west side of Las Chollas Valley, San Diego, California. Length 58.9 mm.; width 66.7 mm.; height approximately 9.2 mm. Aboral surface. P. 117

FIG. 4. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 77.6 mm.; width 86 mm.; height approximately 10.5 mm. Oral surface, with spines. G. P. Kanakoff, collector. P. 118

FIG. 5. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), from Loc. 127 (LAM), at Encanto, Wabash Freeway, Market Street continuation, ¼ mile south of Euclid Avenue, San Diego, California. Length 76 mm.; width 85.3 mm.; height approximately 9.0 mm. Aboral surface. P. 118

FIG. 6. *Dendraster ashleyi* Arnold. Hypotype (Los Angeles County Museum), from 2400 block, east side of Euclid Avenue, San Diego, California. Length 58.5 mm.; width 66.2 mm.; height 9.0 mm. P. 117



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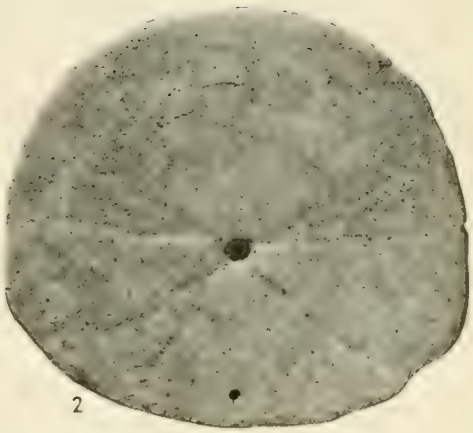

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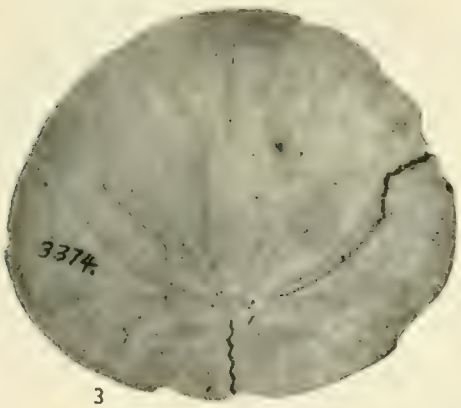

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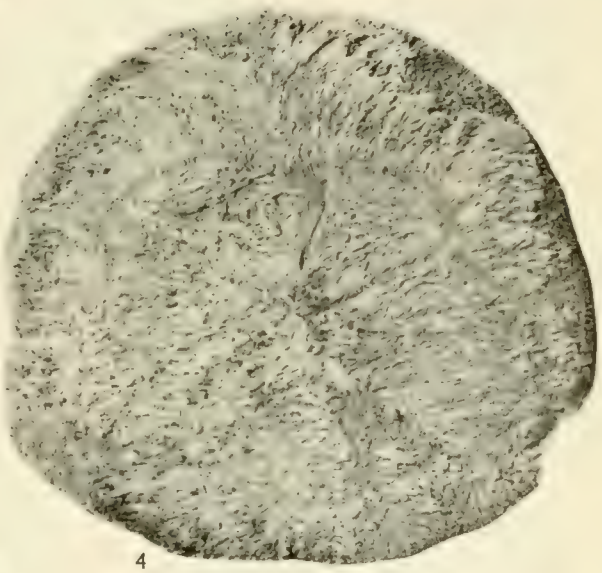

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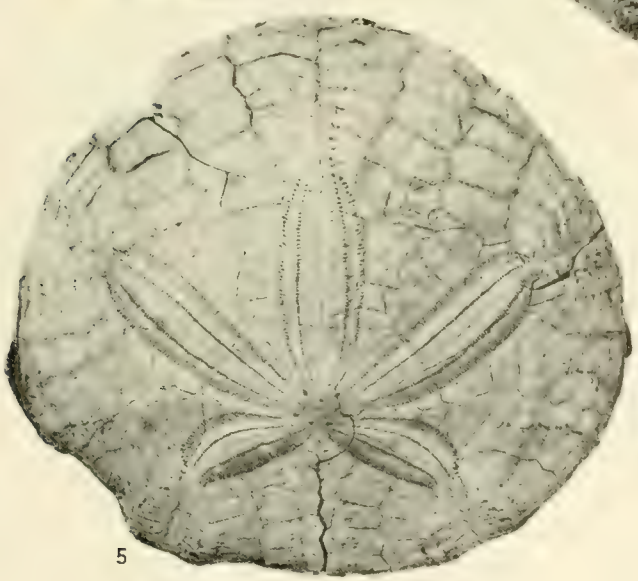

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EXPLANATION OF PLATE 22

FIG. 1. *Dendraster ashleyi* Arnold. Hypotype (Los Angeles County Museum), from Loc. 306 (LAM), on east side of Euclid Avenue, between Federal Boulevard and intersection of Euclid and Home avenues, San Diego, California. Length 58.7 mm.; width 66.8 mm.; height approximately 6.3 mm. Aboral surface. P. 117

FIG. 2. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), from Loc. 294 (LAM), back of house No. 3550 on Dove Street, San Diego, California. Length 20.5 mm.; width 20.6 mm.; height approximately 2.6 mm. Aboral surface of small specimen. P. 118

FIG. 3. *Dendraster ashleyi* Arnold. Hypotype (Cat. No. 3374, University of California at Los Angeles), from Loc. 296 (UCLA), street cut on northwest side of Fairmount extension, 0.4 mile north of intersection with Broadway, on west side of Las Chollas Valley, San Diego, California. Length 59 mm.; width 66.6 mm.; height 8.5 mm. Aboral surface. P. 117

FIG. 4. *Dendraster ashleyi ynezensis* Kew. Hypotype (University of California at Los Angeles), from same locality as specimen shown in fig. 3. Length 61.4 mm.; width 67 mm.; height 9.8 mm. Oral surface of specimen intermediate between *Dendraster ashleyi* and *D. a. ynezensis*. P. 118

FIG. 5. *Dendraster gibbsii humilis* Kew. Hypotype (California Academy of Sciences), from Loc. 12164 (CAS), Pacific Beach, San Diego, California. Length 44.2 mm.; width 48.2 mm.; height 9.5 mm. P. 120

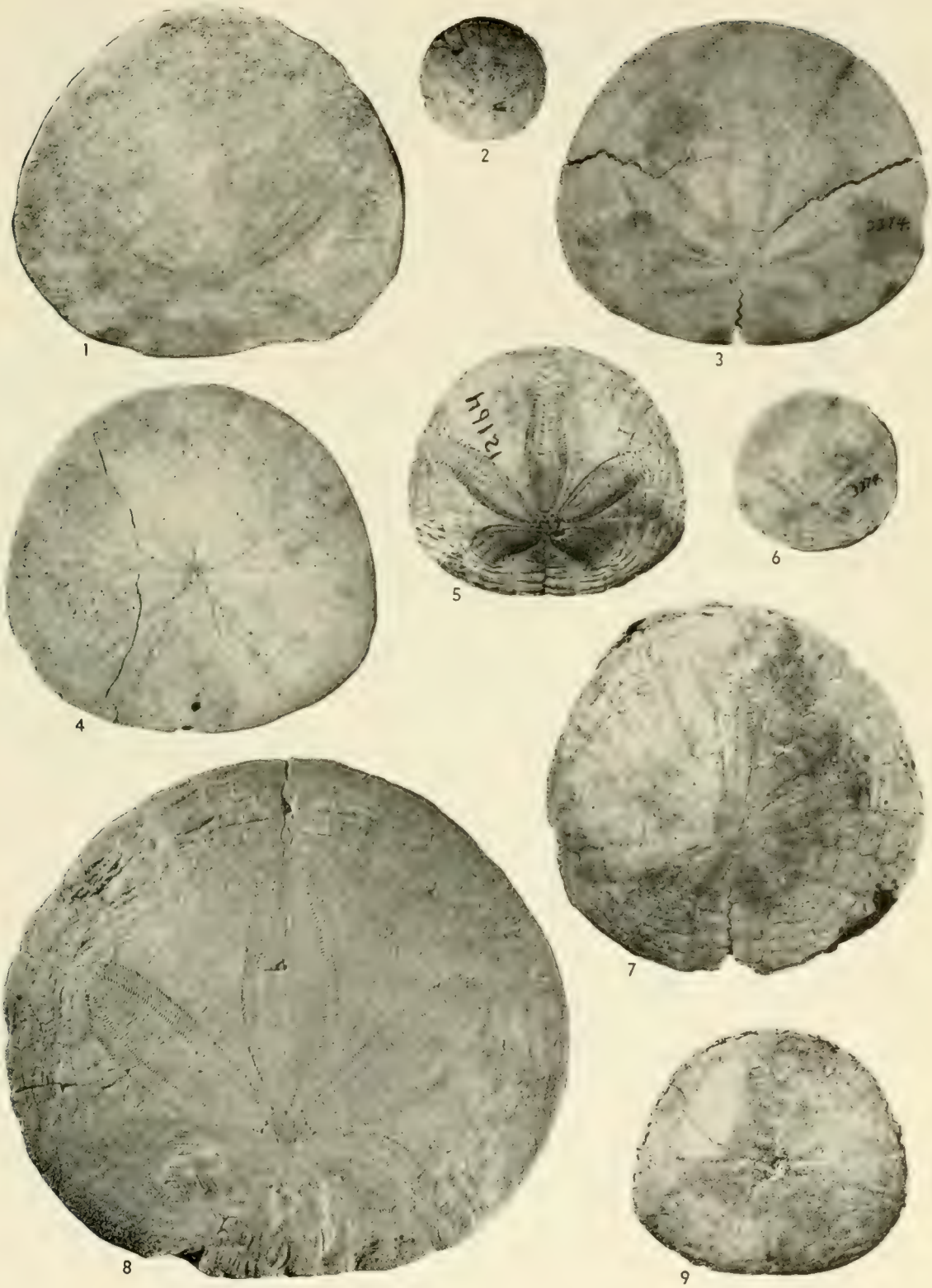
FIG. 6. *Dendraster ashleyi ynezensis* Kew. Hypotype (University of California at Los Angeles), from same locality as specimen shown in fig. 3. Length 28.6 mm.; width 29.9 mm.; height approximately 3 mm. Aboral surface of small specimen. P. 118

FIG. 7. *Dendraster casseli* Grant and Hertlein. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 56.9 mm.; width 60.8 mm.; height approximately 6.3 mm. Aboral surface. P. 120

FIG. 8. *Dendraster ashleyi ynezensis* Kew. Hypotype (No. 4018, University of California at Los Angeles), from Las Chollas Valley, above Market Street bridge, San Diego, California; collected by E. H. Quayle. Length 88.3 mm.; width 98 mm.; height approximately 9.2 mm. Aboral surface.

This form is larger and rounder than typical *D. ashleyi*, and the angle of the bivium is smaller. P. 118

FIG. 9. *Dendraster gibbsii humilis* Kew. Oral surface of specimen shown in fig. 5.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EXPLANATION OF PLATE 23

FIG. 1. *Merriamaster pacificus* Kew. Holotype (No. 448, California Academy of Sciences), from Loc. 537 (CAS), Pacific Beach, San Diego, California. Length 36 mm.; width 35 mm.; height 8.3 mm. Aboral surface. P. 124

FIG. 2. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from Loc. 308 (LAM), 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach, San Diego, California. Length 28.5 mm.; width 27 mm.; height 7.3 mm. Aboral surface. P. 124

FIG. 3. *Merriamaster pacificus* Kew. Oral surface of specimen shown in fig. 2.

FIG. 4. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 2. Length 23 mm.; width 21 mm.; height 4.8 mm. Aboral surface of small specimen. P. 124

FIG. 5. *Merriamaster pacificus* Kew. Oral surface of specimen shown in fig. 1.

FIG. 6. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 28.3 mm.; width 26.7 mm.; height 6.4 mm. Oral surface. P. 124

FIG. 7. *Encope tenuis* Kew. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California; G. P. Kanakoff, collector. Length 104 mm.; transverse diameter (incomplete) 97 mm.; height 12 mm. Aboral surface. P. 126

FIG. 8. *Astropecten armatus* Gray. Hypotype (University of California at Los Angeles), from corner of Market Street and Euclid Avenue, San Diego, California. Length 13.8 mm.; maximum width 12 mm. Aboral surface of fragment of ray. P. 100

FIG. 9. *Astropecten armatus* Gray. Oral surface of specimen shown in fig. 8.

FIG. 10. *Merriamaster* cf. *M. israelskyi* E. K. Jordan and Hertlein. Hypotype (San Diego Society of Natural History), from Balboa Park, San Diego, California. Length 43.4 mm.; width 43.4 mm. Oral surface. P. 122

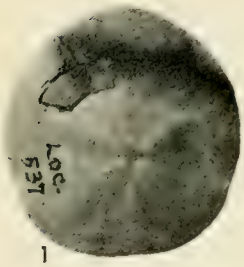
FIG. 11. *Merriamaster pacificus* Kew. Side view of specimen shown in figs. 2 and 3.

FIG. 12. *Merriamaster* cf. *M. israelskyi* E. K. Jordan and Hertlein. Hypotype (Los Angeles County Museum), from Loc. 124 (LAM), 15 feet below floor of Snyder Continuation School, San Diego, California. Length (incomplete) 71.8 mm.; width (incomplete) 41 mm. Oral surface of portion of large specimen. P. 122

FIG. 13.* *Encope tenuis* Kew. Oral surface of specimen shown in fig. 7.

FIG. 14. *Merriamaster* cf. *M. israelskyi* E. K. Jordan and Hertlein. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 12. Length 32.5 mm.; width (incomplete) 29.5 mm. Aboral surface of portion of specimen. P. 122

*Two details in figures 7 and 13 are inexact because of tooling out by the engraver. The small fissure at the central top margin, an imperfection in the fossil, is actually 4 mm. long; and the closed posterior lunule is oval in shape and 4 by 3 mm.



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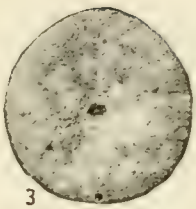
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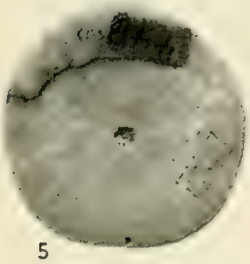
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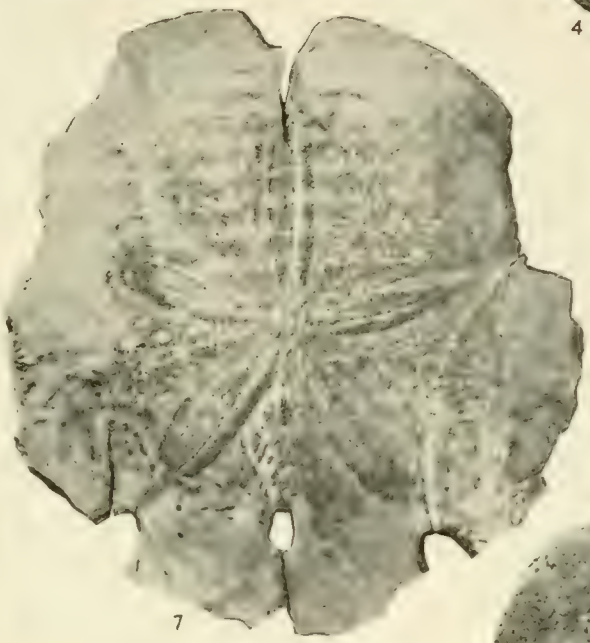
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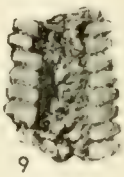
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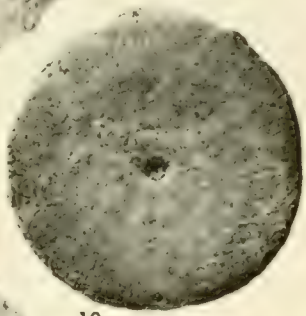
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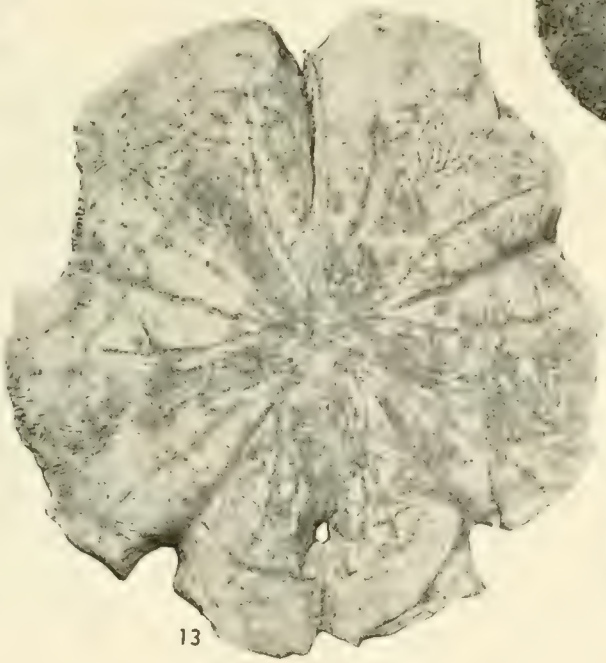
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EXPLANATION OF PLATE 24

FIG. 1. *Lovenia hemphilli* Israelsky. Syntype (No. 918, California Academy of Sciences), from Loc. 12165 (CAS), Pacific Beach, San Diego, California. Length 75 mm.; width 63.1 mm.; height 19.9 mm. Aboral surface. P. 130

FIG. 2. *Lovenia hemphilli* Israelsky. Oral surface of specimen shown in fig. 1.

FIG. 3. *Lovenia hemphilli* Israelsky. Side view of specimen shown in figs. 1 and 2. Anterior end toward the right.

FIG. 4. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian, southwestern San Diego County, California (see U.S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). Height 16.6 mm.; maximum diameter of corallum 6.4 mm. P. 84

FIG. 5. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 15 mm.; maximum diameter of corallum 7 mm. P. 84

FIG. 6. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from Loc. 1183 (CAS), Eagle Street just north of Quince Street and just east of Reynard Way, San Diego, California. Length 18.3 mm.; maximum diameter 2.9 mm. Portion of spine flattened at distal end, as is characteristic of this species. P. 105

FIG. 7. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from same location as specimen shown in fig. 6. Length 21.1 mm.; maximum diameter 2.8 mm. Spine, lacking distal end. P. 105

FIG. 8. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 19.5 mm.; maximum diameter of corallum 9.3 mm. P. 84

FIG. 9. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from Loc. 12163 (CAS), Pacific Beach, San Diego, California. Spine. Length 31 mm.; maximum diameter 3 mm. P. 105

FIG. 10. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from same locality as specimen shown in fig. 6. Spine (incomplete). Length 26.6 mm.; maximum diameter 2.5 mm. P. 105

FIG. 11. *Encope tenuis* Kew. Side view of specimen shown on plate 23, figs. 7, 13. Anterior end toward the right. P. 126

FIG. 12. *Hesperocidaris perplexa* H. L. Clark. Hypotype (San Diego Society of Natural History), from Pacific Beach, San Diego, California. Maximum length of specimen 32.4 mm. Plates with primary and secondary tubercles. P. 105

FIG. 13. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from the same locality as specimen shown in fig. 4. Height 16.4 mm.; maximum diameter of calice 5.6 mm. P. 84

FIG. 14. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from same locality as specimen shown in fig. 6. Spine (incomplete). Length 18.3 mm.; maximum diameter 2.7 mm. P. 105

FIG. 15. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 14.2 mm.; maximum diameter of calice 6.8 mm. P. 84

FIG. 16. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 12 mm.; maximum diameter of calice 7.3 mm. P. 84

FIG. 17. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 17 mm.; maximum diameter of calice 6 mm. P. 84

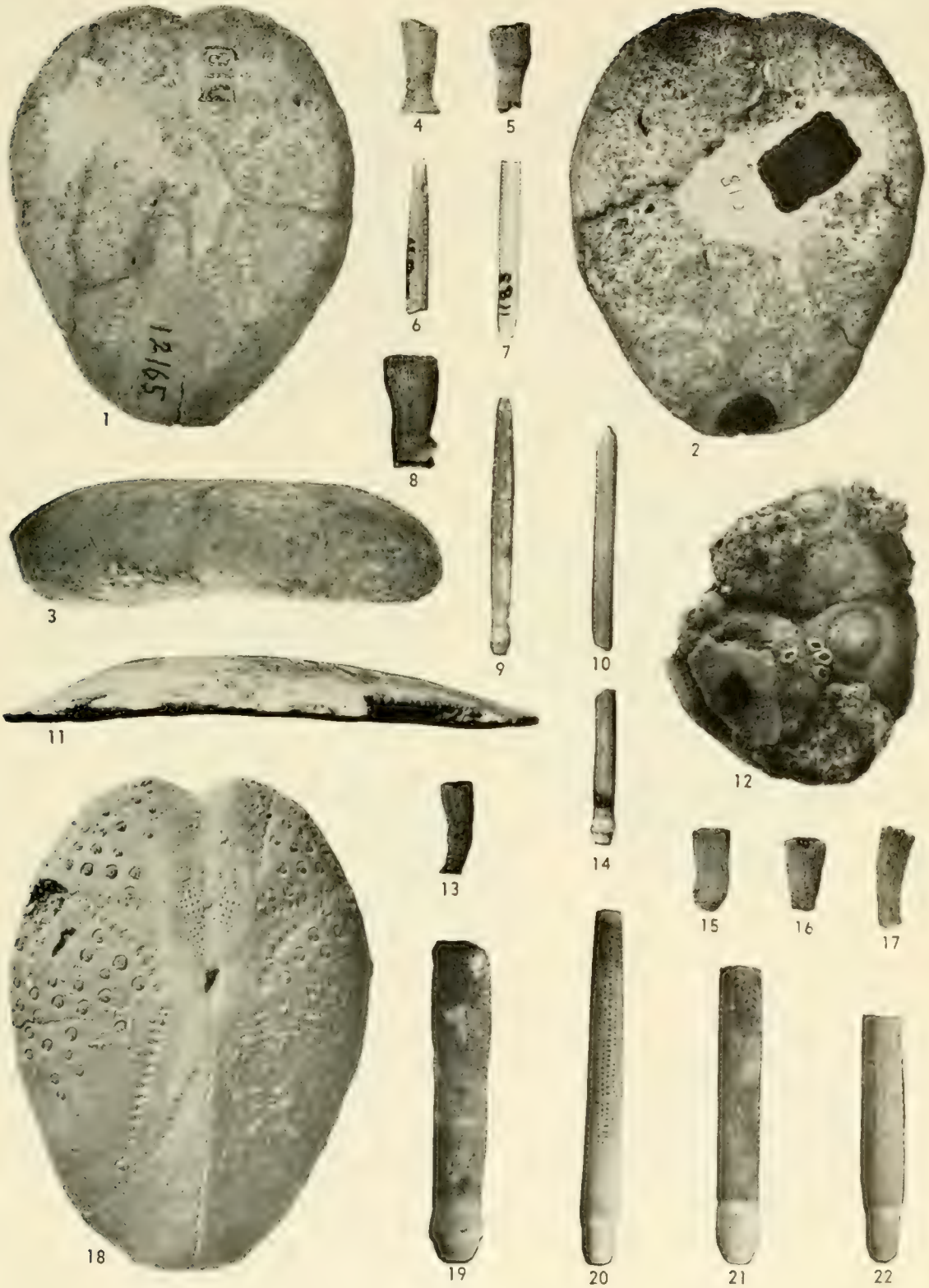
FIG. 18. *Lovenia hemphilli* Israelsky. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 82 mm.; width 62 mm.; height 22 mm. Aboral surface. P. 130

FIG. 19. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine (incomplete). Length 27 mm.; maximum diameter 5.2 mm. P. 103

FIG. 20. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine. Length 30 mm.; maximum diameter 3.4 mm. P. 103

FIG. 21. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine (incomplete). Length 25 mm.; maximum diameter 3.7 mm. P. 103

FIG. 22. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine (incomplete). Length 21 mm.; maximum diameter 3.6 mm. P. 103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EXPLANATION OF PLATE 25

FIG. 1. *Spatangus rarus* Israelsky. Holotype (No. 917, California Academy of Sciences), from Loc. 547 (CAS), Pacific Beach, San Diego, California. Length 72.5 mm.; width 77.0 mm.; height 29.3 mm. Aboral surface. P. 128

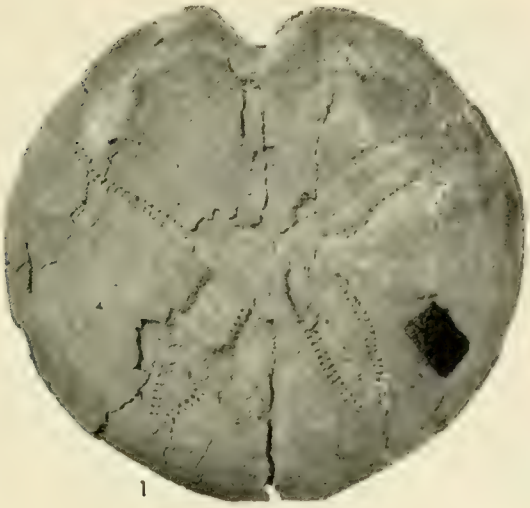
FIG. 2. *Spatangus rarus* Israelsky. Oral surface of specimen shown in fig. 1.

FIG. 3. *Spatangus rarus* Israelsky. Side view of specimen shown in figs. 1 and 2. Anterior end toward the right.

FIG. 4. *Encope tenuis* Kew. Hypotype (San Diego Society of Natural History), from 31st Street and Logan Avenue, San Diego, California. Length approximately 74 mm. Aboral surface. P. 126

FIG. 5. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Paratype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 92 mm.; width 91.8 mm.; height 35.5 mm. Aboral surface. P. 132

FIG. 6. *Merriamaster pacificus* Kew. Aboral surface of specimen (slightly crushed) shown on plate 26, fig. 11.



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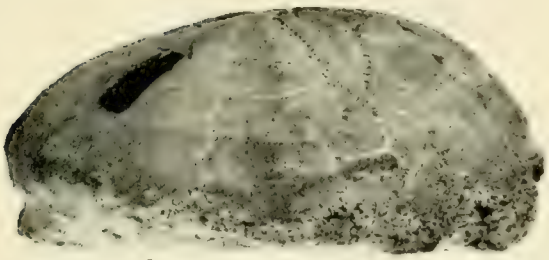

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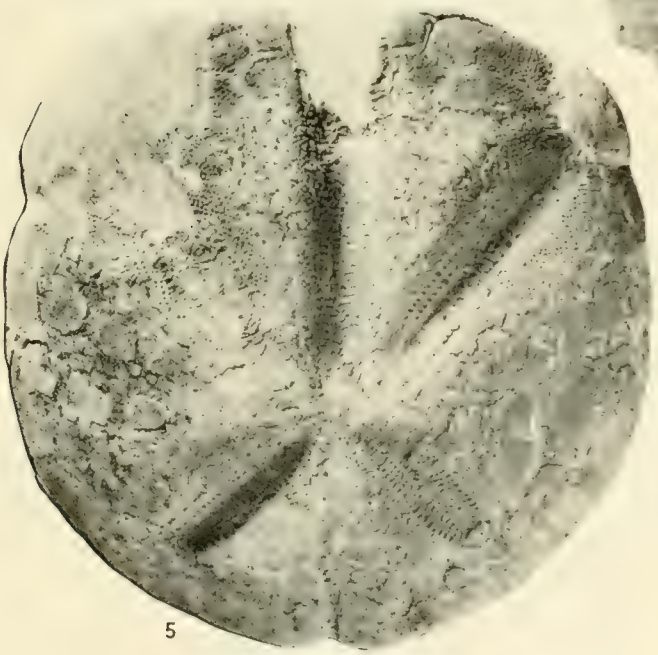

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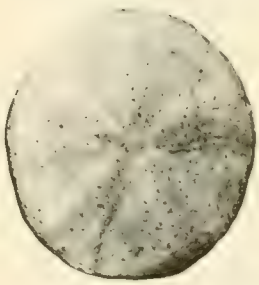

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EXPLANATION OF PLATE 26

FIG. 1. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Holotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 91.5 mm.; width 90 mm.; height 34.5 mm. Aboral surface. A portion of the right side of this specimen is covered with hard concretionary sandstone. P. 132

FIG. 2. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Posterior end of specimen shown in fig. 1.

FIG. 3. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Oral surface of specimen shown in figs. 1 and 2.

FIG. 4. *Echinometra* sp. Hypotype (California Academy of Sciences), from Loc. 1413 (CAS), Pacific Beach, San Diego, California. Maximum diameter 19.2 mm.; height 8.3 mm. Side view. P. 114

FIG. 5. *Echinometra* sp. Oral surface of the specimen shown in fig. 4.

FIG. 6. *Arbacia incisa* A. Agassiz. Hypotype (California Academy of Sciences), from Pacific Beach, San Diego, California. Diameter 7.6 mm.; height 3.8 mm. Side view. P. 108

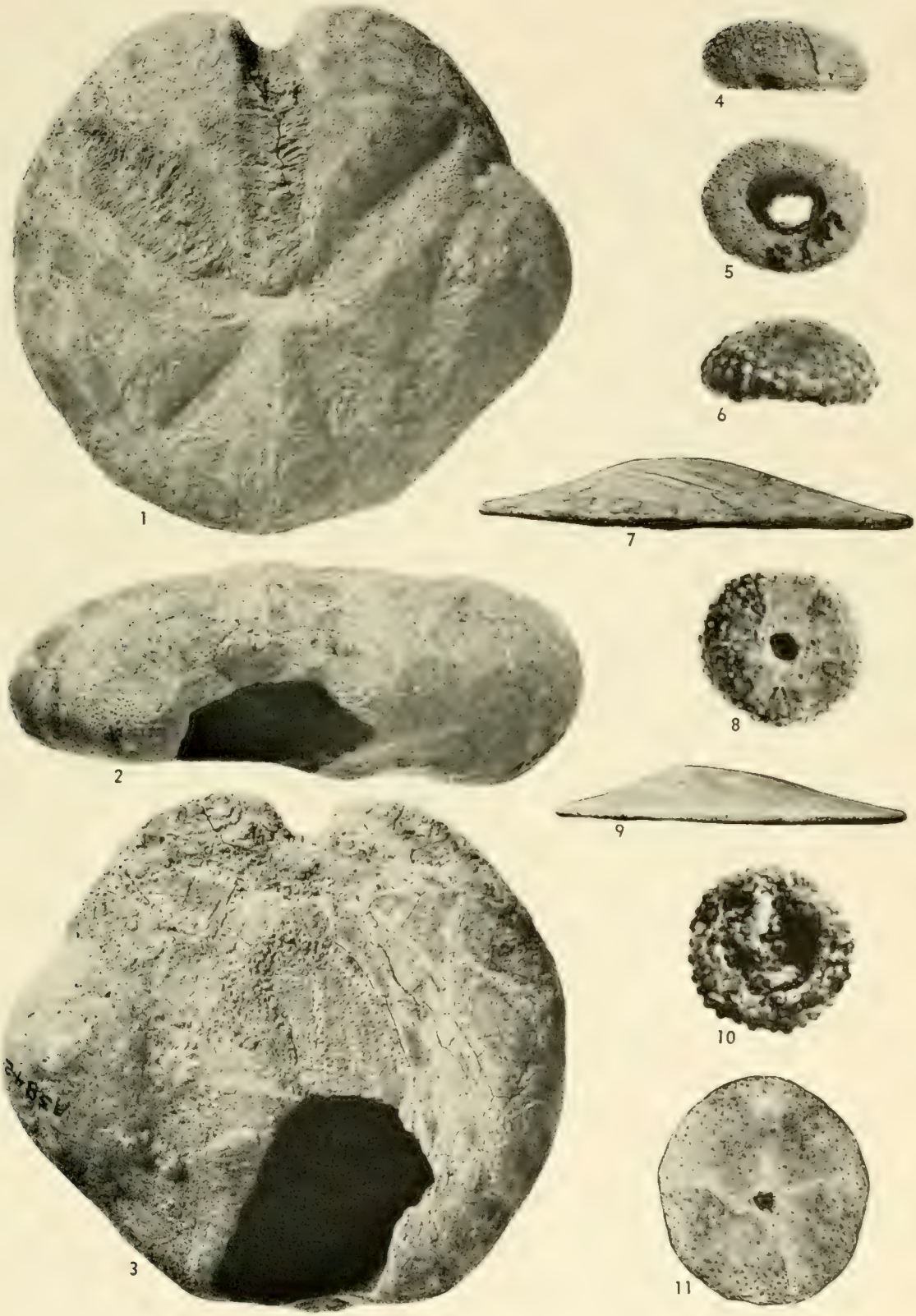
FIG. 7. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), side view of specimen shown on plate 21, fig. 5. Anterior end toward the right. P. 118

FIG. 8. *Arbacia incisa* A. Agassiz. Aboral surface of specimen shown in figs. 6 and 10.

FIG. 9. *Dendraster ashleyi* Arnold. Side view of specimen shown in plate 21, fig. 6.

FIG. 10. *Arbacia incisa* A. Agassiz. Oral surface of specimen shown in figs. 6 and 8.

FIG. 11. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 24.3 mm.; width 22.8 mm.; height 6.4 mm. Oral surface of a slightly crushed specimen. See also plate 25, fig. 6. P. 124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1898 – 1972

THE GEOLOGY AND PALEONTOLOGY OF THE MARINE PLIOCENE OF SAN DIEGO, CALIFORNIA (PALEONTOLOGY: PELECYPODA)

LEO GEORGE HERTLEIN
CALIFORNIA ACADEMY OF SCIENCES
AND
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UNIVERSITY OF CALIFORNIA AT LOS ANGELES

SAN DIEGO
SOCIETY OF NATURAL HISTORY

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LEO GEORGE HERTLEIN

1898-1972

Leo George Hertlein died on 15 January 1972. Dr. Hertlein was Emeritus Curator of Geology at the California Academy of Sciences, where he had worked from 1925 until his retirement in 1970. The October 1970 issue of *The Nautilus* honors Dr. Hertlein on the occasion of his retirement, and contains a biographical sketch, a list of his publications, a list of the taxa he proposed and those taxa proposed in his honor.

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FOREWORD

This portion of this monograph deals with the Pelecypoda of the San Diego Formation. The major collections upon which the present paper is based are chiefly those in the California Academy of Sciences, the Los Angeles County Museum, San Diego Society of Natural History, and the University of California at Los Angeles. These were supplemented by additional material from the collections at Stanford University and San Diego State College.

Special acknowledgment is due Mr. George P. Kanakoff, Los Angeles County Museum, who generously lent an extensive collection which he and his associates assembled in the San Diego area. This collection furnished the basis for records of many species not previously reported from the San Diego formation. A collection earlier loaned by Mrs. Kate Stephens, former Curator of Marine Invertebrates at the San Diego Society of Natural History, was supplemented by additional specimens sent by Dr. Edward C. Wilson, former Curator of Invertebrates (now with Los Angeles County Museum of Natural History), and Mr. Emery P. Chace, former Curator of Mollusks, in that institution.

Collections in greater part assembled by the late Ernest H. Quayle, which are the property of the San Diego Society of Natural History and of the University of California at Los Angeles, were lent by Mr. Takeo Susuki and Dr. Willis P. Popenoe of the latter institution.

The present paper could not have appeared in its present form without the aid and cooperation of many individuals. We are especially grateful to Dr. G D. Hanna, Curator of the Department of Geology, to Barry Roth, Curatorial Assistant in the same Department, and to Allyn G. Smith, Associate Curator of the Department of Invertebrate Zoology, California Academy of Sciences, who aided with advice and constructive criticism on many occasions. Ray Brian, librarian in the same institution aided us by making available certain of the literature pertinent to this study, and Dr. Anatole Loukashkin, Research Associate in the Department of Ornithology and Mammalogy, kindly furnished translations of some articles published in the Russian language. Others who aided in various ways include: Dr. A. Myra Keen and Dr. Eugene Coan, Stanford University; Dr. J. Wyatt Durham, and Mr. Joseph H. Peck, Jr., University of California, Berkeley; Dr. Joshua L. Bailey, Jr., San Diego Society of Natural History; the late Dr. Edwin C. Allison, and Professor E. Dean Milow, San Diego State College; Dr. Harald A. Rehder, Dr. G. Arthur Cooper, and Dr. Joseph Rosewater, United States National Museum; Dr. William K. Emerson, American Museum of Natural History; Dr. R. Tucker Abbott and Dr. Robert R. Robertson, Academy of Natural Sciences of Philadelphia; Dr. Ruth Turner, Museum of Comparative Zoology, Harvard University; Mr. F. Stearns MacNeil, Fort Myers, Florida; Mrs. Ellen Moore, United States Geological Survey, San Diego, California; Dr. Hendryk B. Stenzel, Shell Development Company, Houston, Texas; Dr. André Franc, Laboratoire de Malacologie, Museum National d'Histoire Naturelle, Paris. The aid of the other individuals will be acknowledged in the appropriate places in the text.

Most of the photographs used for illustrations on the plates were made by Mr. Maurice C. Giles, Photographer, California Academy of Sciences, but photographs of some of the small specimens were furnished by the late Dr. G D. Hanna and Allyn G. Smith of the same institution.

The line drawings from which text figures 7, 8, 9, 10, and 13 were made, were drawn by the late Ernest H. Quayle. Text figures 11 and 12 are from drawings by Mrs. Dorothy Ludlow. The typescript was prepared by Mrs. Ludlow and Mrs. Enid Cook. Mrs. Margaret Hanna kindly retouched many of the photographs.

The cost of photography was provided by a grant, No. G17939, National Science Foundation. The authors are grateful to the individuals whose efforts facilitated this grant, and especially to Dr. David D. Keck, former Program Director, Dr. Walter H. Hodge, present Program Director, and Miss J. Frances Allen, Associate Program Director for Systematic Biology.

NEW GENERIC AND SUBGENERIC NAMES

Axinola, new subgenus
Irusella, new genus

NEW SPECIFIC AND SUBSPECIFIC NAMES

Nucula (Ennucula) balboana, new species
Mytilus (Crenomytilus) coalingensis sternbergi, new subspecies
Chlamys (Chlamys) hastata ellisi, new subspecies
Chlamys (Argopecten) abietis abbotti, new subspecies
Lima (Limaria) orcutti, new species
Aligena diegoana, new species
Bornia frankiana, new species
Dosinia ponderosa diegoana, new subspecies
Chione allisoni, new species
Chione kanakoffi, new species
Psephidia stephensae, new species
Semele ashleyi, new species
Thracia kanakoffi, new species

ABBREVIATIONS

Abbreviations following locality numbers cr specimen numbers refer to the following institutions:

(ANSP) — Academy of Natural Sciences of Philadelphia
(CAS) — California Academy of Sciences
(LAM) — Los Angeles County Museum Invertebrate Paleontology
(SD) — San Diego Society of Natural History
(SDSC) — San Diego State College
(SU) — Stanford University
(UC) — University of California (Berkeley)
(UCLA) — University of California at Los Angeles
(USGS) — United States Geological Survey
(USNM) — United States National Museum

REFERENCES AND SUPPLEMENTARY DATA

All references and supplementary data are numbered consecutively within the text (in parentheses); these follow the main body of the text, starting on page 345.

PHYLUM MOLLUSCA LINNAEUS

CLASS PELECYPODA GOLDFUSS

The Pelecypoda from the San Diego formation identified in the present study, are here arranged in 4 subclasses, 8 orders, 22 superfamilies, 39 families, 82 genera and 144 species and subspecies of which 10 are not positively identified but are compared [cf. or aff.] with known species and 2 additional ones are cited as to genus only. One genus, one subgenus, 9 species and 4 subspecies are described as new. The occurrence of 11 species, one cited only as to genus, reported by other authors as occurring in the San Diego Formation, was not confirmed during the present faunal study.

The systematic arrangement in general is a combination derived from that of Dall (1)* and that of Thiele (2) with minor modifications from Cox and Newell. Families and superfamilies both are attributed to the first author who mentioned an acceptable latinized suprageneric category applicable to the group. Da Costa (3) was one of the earliest authors to apply latinized family categories to suprageneric groups of pelecypods. For example, "Family 9, is the Tellinae of Tellens." These denominations appear to be as acceptable nomenclatorially for suprageneric categories as are names used in the vernacular plural by Blainville and by Lamarck, such as "Les Tellinacées" which was latinized by later authors to Tellinidae and Tellinacea. A volume by Haas (4) contains a wealth of information concerning the classification and biology, including an extensive bibliography dealing with pelecypods. A work by Franc (5) also deals with a general treatment of this class. Publications by Habe (6), Korobkov (7), Cox (8), Newell (9) and Vokes (10) also are useful in ascertaining modern systematic arrangements of Cenozoic bivalves.

A recent publication, part of "Treatise on Invertebrate Paleontology," (11) contains an important discussion of the general features, and a comprehensive, systematic treatment of the supraspecific categories of the Pelecypoda. A paper by Böggild (12) deals with the shell structure of mollusks and a paper by Oberling (13) contains a discussion of the structural features of pelecypod shells.

The maximum depth ranges cited for the genera and species in this paper are based upon published records (14). These, however, can only be considered as representing approximate depths to which members of the genera may be found. Many of these records, where taken from the earlier literature, undoubtedly refer to the genera in a broad sense.

SUBCLASS PRIONODESMATA NEUMAYR
ORDER PALAEOTAXODONTIDA KOROBKOV
SUPERFAMILY NUCULACEA GRAY (15)
FAMILY NUCULIDAE GRAY (16)

Shell equivalve, up to 50 mm in length; roughly trigonal or oval in outline; inequilateral; posterior side short, often truncate; anterior side longer than posterior, with anterior extremity rounded. Beaks posterior, opisthogyrate. A true lunule (behind the umbones) wanting; the pseudo-lunule, though sometimes lanceolate, is seldom well-defined. Below the beaks the escutcheon (occupying the position of the lunule of many pelecypods) is often heart-shaped. Prodissoconchs smooth. Sculpture, when present, consists of concentric ribs only, concentric ribs and radial ribs; bifurcating radial ribs, or modifications and combinations of these. Inner ventral margins smooth or denticulate (crenulate or pectinate). Dentition taxodont, with the longer row of teeth generally extending over the chondrophore (ligament-support). No external ligament, but an internal resilium. Pallial line entire. Shells with nacreous interiors (at least when the animal was alive); in many, if not all, species there is a differentiation of shell material, but no prismatic layer. Shells not gaping, and commonly each exhibits two subequal adductor muscle scars and additional muscle scars. The type genus is *Nucula* Lamarck, 1799. (Schenck, 1934.) Ordovician to Recent.

Remarks. — Members of this large family first appeared early in the Paleozoic era. The pearly inner layer of the shell and the presence and arrangement of the small, numerous, curved, taxodont teeth on the hinge suggest an early origin for this group. The gill structure of Recent forms is protobranch.

Schenck (17) discussed the classification of this family, as did Cox (18) who dealt especially with the derivation of the Mesozoic and Paleozoic representatives. The structure of the shell and the classification of this group was discussed recently by Van de Poel (19).

Key to Genera and Subgenera of Nuculidae

A. Shell with divaricate sculpture . . . . . *Acila*

  a. Valves with a groove parallel to posterior margin . . . (subgenus) *Acila s. s.* (20)
  aa. Valves lacking groove parallel to posterior margin . . . . (subgenus) *Truncacila*

B. Shell smooth or with radial or cancellate sculpture . . . . . *Nucula*

  a. Inner margin of shell with denticles

    b. Concentric sculpture coarse, lamellate . . . . (subgenus) *Lamellinucula*
    bb. Concentric sculpture fine, not lamellate . . . (subgenus) *Nucula s. s.* (20)

  aa. Inner margin of shell smooth . (subgenus) *Ennucula*

GENUS *NUCULA* LAMARCK

Nucula Lamarck, Mém. Soc. d'Hist. Nat. Paris, p. 87, 1899. Sole species: *Arca nucleus* Linnaeus. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 110, 1931. "Type (by monotypy), *Arca nucleus* Linnaeus." — Schenck, Bull. Mus. Roy. d'Hist. Nat. Belgique, Vol. 10, No. 20, p. 18, 1934. "(Type by monotypy: *Arca nucleus* Linné)." — Hertlein and

*All references and supplementary data are numbered consecutively within the text (in parenthesis); these follow the main body of the text, starting on page 345.

Strong, Zoologica, Vol. 25, Pt. 4, p. 379, 1940. "Type (by monotypy): *Arca nucleus* Linnaeus."

Type species (by monotypy). — *Arca nucleus* Linnaeus [Syst. Nat., ed. 10, p. 695, 1758. "Habitat in Europa." Illustrated by Schenck, 1934, pl. 1, fig. 8; pl. 3, fig. 2; pl. 4, figs. 4, 4a, 4b; pl. 5, figs. 1, 1a. — Schenck, Proc. Malacol. Soc. London, Vol. 21, Pt. 4, fig. 1 (p. 260), March, 1935].

Range. — Jurassic to Recent. Recent in all seas; greatest number in temperate and boreal regions, from a few meters to a depth of over 3658 meters (2000 fathoms).

Description. — Shell closed, not gaping; profile ovate-trigonal; a "pouting" of the escutcheonal area, which the radial ribs do not cross; beaks opisthogyrate, appressed; prodissoconch unornamented; radial ribs faint, low, wide and flat, often difficult to see on the middle part of the shell, but they are more distinct near the ventral margin where they form the "pectinate margin"; interspaces narrow, about one-tenth the width of the ribs; interior nacreous; pallial line simple; two subequal adductor muscle scars and additional muscle scars; longer (anterior) row of teeth arched, with 16± to 24± teeth; the shorter (posterior) row straight with 7± to 11±; axis of chondrophore forms an arc of a circle of which the arcuate dorsal margin is a part. (Schenck, 1934).

Remarks. — Species of this genus are generally small, many of them do not exceed 10 mm in length. *Nucula mirifica* Dall (21) living in the waters of Japan was said by its author to be probably the largest living smooth *Nucula* known. It attains a length of 36 mm. Large specimens of *Nucula compressa* Philippi from the Chattian (late Oligocene) of Belgium were reported by Schenck to be 29.3 mm long.

Trueman (22) published the results of a study of the ligament of *Nucula*. Ford (23) pointed out that the concentric rings of the shell of *Nucula nitida* do not lend themselves to a simple interpretation of the rate of growth. The habits of two species of this genus living in north European waters were described by Allen (24).

Schenck in 1934 stated that over one thousand specific names have been associated with the genus *Nucula*. A few species have been described from Tertiary strata of western North America but only two of those have been reported from beds of Pliocene age. About 20 to 22 species are known from west American waters between Bering Sea and Cape Horn.

SUBGENUS *ENNUCULA* IREDALE

Ennucula Iredale, Rec. Australian Mus., Vol. 18, No. 4, pp. 202, 231, June 29, 1931. "Type *Nucula obliqua* Lamarck." — Schenck, Bull. Mus. Roy. d'Hist. Nat. Belgique, Vol. 10, No. 20, p. 37, June, 1934. "(Type: *Nucula obliqua* Lamarck.)" — Hertlein and Strong, Zoologica, Vol. 25, Pt. 4, p. 382, December 31, 1940. "Type (by original designation): *Nucula obliqua* Lamarck."

Type species (by original designation). — *Nucula obliqua* Lamarck [Hist. Nat. Anim. s. Vert., Vol. 6, p. 59, 1819. "Habite les mers australes, au Cap aux Huitres." Illustrated by Schenck, 1934, pl. 3, figs. 4, 4a, 4b; pl. 4, figs, 3, 3a, 3b. Australia, Recent].

Range. — Miocene (and probably earlier) to Recent.

Original descriptions. — The type species of *Nucula* is *nucleus* Linné, a European species which differs appreciably from antipodean shells so classed, the latter having a notably oblique chondrophore, above which the teeth become much smaller, and the angle of opposition of the two rows of teeth is scarcely marked; further, the edge of the European shell is strongly denticulate, whereas ours is practically smooth. (Iredale, 1931.)

Remarks. — The similarity of *Ennucula* to *Leionu-*(25), which latter genus was described by Quenstedt one year earlier, was mentioned by Schenck (1934, p. 35) and later by Ichikawa and Maeda (26).

Schenck assigned subgeneric status to *Ennucula* which he placed under the genus *Nucula*. Van de Poel, more recently, considered the species of Nuculidae with non-radial structure to be referable to the genus *Nuculoma* Cossman (see Schenck, 1934, p. 26, pl. 4, figs. 5, 5a, 5b, 5c) whose type is *Nucula castor* d'Orbigny, a Jurassic species. On this basis he assigned *Ennucula* subgeneric status under *Nuculoma*. We have not studied specimens of *N. castor* and for the present at least, we leave *Ennucula* in the category assigned to it by Schenck.

About 20 species were placed in *Ennucula* by Schenck and he listed thirteen additional species which may be referable to this subgenus. Six species from the Cenozoic of western North America have been referred to *Ennucula*. One new species from the Pliocene of San Diego is added in the present paper.

Nucula (Ennucula) balboana n. sp.
Plate 27, Figures 1, 2, 3, 4

"*Nucula*, sp. n. according to Dr. Cooper," Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, December, 1874. "Well at San Diego." — Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 85, August, 1889. Dall's (1874) record cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Orcutt's citation of Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record cited. (Not *Nucula exigua* Sowerby).

Holotype and paratypes in the California Academy of Sciences Department of Geology Type Collection, from the San Diego well in Balboa Park, San Diego, California; H. Hemphill, collector; Pliocene.

Range. — Known only from the type locality.

Descriptions. — Shell ovately triangular, smooth, beaks opisthogyrate, placed near posterior end, a lanceolate depressed area beneath them; the posterior margins of the valves slightly projecting; a narrow area along the anterior dorsal margin slightly depressed; anterior margin broadly rounded, the anterior end elliptically rounded, the posterior end slightly rounded and abruptly truncated; surface of valves with fine concentric lines of growth, toward the anterior margin with occasional minute constrictions; inner margin of shell smooth and devoid of denticles. Portions of two paratypes reveal the presence of about 18 teeth in the anterior series and about 8 or 9 in the posterior series. The chondrophore projects obliquely anteriorly. Dimensions of holotype: length, 13.4 mm; height, 10.7 mm; convexity (both valves together slightly gaping due to enclosed sediment), 7.2 mm.

Remarks. — The species here described as new closely resembles *Nucula quirica* Dall (27) but differs in

that the shell is more elongate in proportion to the height, the anterior margin is correspondingly less broadly rounded, and so far as known there is no trace of fine radial striae on the interior of the valves.

Schenck (28) considered *N. quirica* to be a probable synonym of *Nucula bellotii* A. Adams (29) but judging from his illustrations (30) of that species the shell is less abruptly truncated posteriorly and the anterior dorsal margins of the valves are more inflated than that of Dall's species.

The present specimens, collected by Henry Hemphill from the San Diego well, are probably from the original lot which Dall identified as a new species of *Nucula* which "Looks much like *N. tenuis.*"

SUBGENUS *LAMELLINUCULA* SCHENCK

Lamellinucula Schenck, Jour. Paleo., Vol. 18, No. 1, p. 97, January, 1944.

Type species (by original designation). — "*Nucula lamatavica* Odhner (1943, p. 206), new name for *Nucula rugosa* Odhner (1919, pp. 23-24, pl. 2, figs. 15-18); Recent, Madagascar." [See Odhner, K. Svensk Vetenskaps Arkiv för Zool., Bd. 12, No. 6, p. 23, pl. 2, figs. 15-18, 1919. Also illustrated by Schenck, 1944, p. 98, fig. 1.]

Range. — Eocene (31) to Recent. Recent, worldwide, in 5 to 219 meters (3 to 120 fathoms), questionable below 1829 meters (1000 fathoms) according to Schenck.

Original description. — The subgenus is proposed for nuculid pelecypods ranging in length up to about 25.0 mm; shell closed, not gaping; dorsal margin straight to gently arched; anterior extremity bluntly rounded (see fig. 1); ventral margin convex; posterior margin straight to convex; lunule and escutcheon indistinct to moderately well defined; beaks inturned, opisthogyrate; interior nacreous; taxodont dentition consisting of about 12 to 26 teeth in the anterior (long) series, 4 to 12 in the posterior (short) row; chondrophore distinct, sometimes heavy; two subequal adductor muscle scars and accessory scars as in other members of the family; pallial line entire; inner ventral margin denticulate (crenulate, crenate); incised, lamellate concentric sculpture more conspicuous than radial ribs or striae; from two to eight concentric ribs per millimeter. (Schenck.)

Remarks. — Twenty species and subspecies, described under the genus *Nucula*, were referred to *Lamellinucula* by Schenck and he mentioned thirteen others which may be referable to this category.

Glibert and Van de Poel (Mém. Inst. Roy. Sci. Nat. Belgique, Deuxième Sér., Fasc. 77, p. 15, 1965) suggested the possibility that the type of ornamentation on *Lamellinucula* may be polyphyletic.

Nucula (Lamellinucula) exigua Sowerby
Plate 27, Figures 5, 6

Nucula exigua Sowerby, Proc. Zool. Soc. London for 1832, p. 198 (issued March 13, 1833). — Sowerby, Conch, Illustr., Nuculae, Catalogue, Pt. 16, p. 6, pl. 16, figs. 24, 24*, issued January 18, 1833. (Reprinted Cat., p. 6, 1841.) "Bay of Caraccas." — Hanley, Thes. Conch., Vol. 3, p. 154, pl. 229, (Nuculidae, pl. IV), fig. 136, 1860. "Bay of Caracas, W. Columbia." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. "well-digging in stratum B^2." Pliocene. Other localities (pp. 11, 27), probably Pleistocene. — Cooper, Calif. State Mining Bureau, Seventh Ann. Rept. State Mineralogist, Vol. 7, p. 254, 1888. "Pl. — San Diego well." — Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 86, August, 1889. Dall's record (1874) cited. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 577, 1898. "San Diego, California, well." "Pliocene." — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 60, 1919. Dall's record (1874) cited — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 13, 1924. "In the Pliocene of San Pedro and San Diego, California." Also Recent.

Nucula (Nucula) exigua Sowerby, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 111, 1931. "San Diego well" (Dall's record, 1898, cited), Pliocene. Also cited from Merced and Wildcat Formations and Pleistocene and Recent. — Schenck, Jour. Paleo., Vol. 13, No. 1, p. 36, pl. 6, figs. 1-8, 11, 1939. Recent. — Hertlein and Strong, Zoologica, Vol. 25, Pt. 4, p. 381, pl. 1, figs. 4, 5, 1940. Corinto, Nicaragua, Recent. Also earlier records.

Nucula exiqua Sowerby, Palmer, Geol. Soc. Amer., Mem. 76, p. 61, pl. 1, figs. 6, 7, 1958. Syntype of "*N. suprastriata* Cpr.", from " 'Catalina 30 fms. Cooper'." Not *Nucula suprastriata* Carpenter in Arnold, 1903.

Nucula (Nucula) exiqua Sowerby, Olsson, Mollusks of Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 56, pl. 1, figs. 2, 2a, 2b, 10, 10a, 1961. Lower California to Peru.

Type specimen. — British Museum (Natural History).

Type locality. — "Hab. ad Columbiam Occidentalem (Bay of Caraccas)." [Ecuador, Lat. 00° 35′ S.] "A single specimen found in sandy mud at nine fathoms depth."

Range. — Middle Pliocene to Recent. Recent from Bahía Tórtolo (Turtle Bay), Lower California, to the Gulf of California, and south to Ecuador, in 16 to 24 meters (9 to 13 fathoms); 1207 to 1895 meters (660 to 1036 fathoms) (Dall).

Occurrence in San Diego Fm. — U.C.L.A. 312.

Original description. — Nuc. testâ parvâ, obliquè ovatâ, albicante, pellucidâ, concentricè sulcatâ; latere postico longiore, subacuminato, antico brevissimo: long. 0.2, lat. 0.1, alt. 0.15 poll. (Sowerby.)

Remarks. — This species was reported by Dall from diggings of the San Diego well and that record was cited by several authors.

One left valve and two imperfect right valves, one of which is about 5 mm in altitude, are present in the collections from near the United States-Mexico boundary. These retain traces of radial striae, crossing the stronger concentric ribbing, over most of the surface of the valves. This feature, however, varies in a series of Recent specimens of this species as does the amount of escutcheonal projection.

Nucula suprastriata Carpenter in Arnold (32), a similar species or subspecies, is said to differ from *N. exigua* in the greater size (up to 7 mm in length), the more impressed lunule and escutcheon, and in that the radial sculpture usually is present only toward the base of the valves. These differences, as mentioned by Schenck, are found to be less constant when a large series of specimens is examined. Schenck concluded that greater size is the

most reliable criterion for separating *N. suprastriata* from *N. exigua.*

A consideration of the foregoing in connection with study of the present fossils from the San Diego formation leads us to refer them to *N. exigua.*

Adequate discussion and illustration of Recent specimens of *Nucula exigua* have been given by Schenck and by Hertlein and Strong.

Nucula paytensis A. Adams (33) as pointed out by Hertlein and Strong, apparently is more rounded in outline and the escutcheon area is more projecting than that of *N. exigua.* Schenck (1944, p. 98) considered it to be a synonym of *N. exigua* and Olsson (1961, p. 56) suggested that intergradation between the two may occur.

Nucula vieta Guppy described from strata of late Miocene age in Trinidad is a very similar species (see Jung, Bull. Amer. Paleo., Vol. 55, No. 247, p. 316, pl. 13, figs. 4-7, 1969).

Nucula cahuitensis Olsson (34) described from strata of Miocene age in Costa Rica, was compared by its author with *N. exigua.*

Nucula venezuelana Weisbord (35) described from beds of Pliocene age in Venezuela is another similar species.

GENUS *ACILA* H. AND A. ADAMS

Acila H. and A. Adams, Gen. Rec. Foss. Moll., Vol. 2, p. 545, January, 1858. Species cited: "*castrensis*, Hinds," "*divaricata*, Hinds," "*mirabilis*, Adams and Reeve." — Kobelt, Illustr. Conchylienbuch, Bd. 2, Lief. 10-11, p. 371, 1881. "Typus *Nucula divaricata* Hinds (Taf. 109 Fig. 18)." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 112, November 3, 1931. Type as designated by Stoliczka, 1871. — Schenck, Geol. Soc. Amer., Spec. Papers No. 4, p. 23, 1936. Type as designated by Stoliczka, 1871.

Type species (designated by Stoliczka, Mem. Geol. Surv. India, Palaeo. Indica, Ser. 6, Cret. Fauna South. India, Vol. 3, pp. XXI, 325, 1871). — "*N. divaricata*, Hinds, is the type." [Proc. Zool. Soc. London for 1843, p. 97, issued December, 1843. "Hab. China Sea; from eighty-four fathoms." "Cab. Belcher." Illustrated by Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, p. 62, pl. 18, fig. 4, 1844 (January, 1845, on cover of Pt. 3). — Schenck, 1936, pl. 15, figs. 1-10, text fig. 8 (1, 2).]

Range. — Early Cretaceous (Aptian) to Recent. Recent in Indo-Pacific waters at depths of about 9 to 1500 meters (5 to 820 fathoms) but usually in less than 914 meters (500 fathoms), in fine-grained sediment, and bottom temperatures between 4.4° to 21.1° C. (40° to 70° F.) but species have been taken in 1.11° C. (34.0° F.) and 23.9° C. (75° F.).

Description. — Like *Nucula* but often larger (max. length about 50 mm), the surface sculptured with a characteristic pattern of parallel divaricating and more or less radial riblets which appear as if stacked or packed close together the main line of divarication extending from the umbo across the middle of the shell disk to the ventral margin, the peaks of their inverted V's forming a line of sharp, acute angles pointing toward the beak. A secondary line of reversed divarication may be developed along the posterior rostral side which forms a shallow sinus ending in a slight bulge or pout at the margin. (Olsson, A. A., Mollusks of the Tropical eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 57, 1961.)

Remarks: The shells of this genus are closed, equivalve, inequilateral and trigonal or ovate to quadrangular in outline similar to *Nucula.* They attain a length of about 50 mm and a height of often about 75 per cent of the length. The beaks are opisthogyrate; interior nacreous; dentition taxodont.

A thorough monographic study of *Acila* and its species by Schenck (36) in 1936 has been the source of most of our information concerning the ecology of this group. According to Schenck *Acila s. s.* is known to range from "Oligocene (?) to Recent."

Key to Subgenera of *Acila*

A. Well defined rostral sinus present . . . *Acila s. s.*

B. Well defined rostral sinus lacking . . . *Truncacila*

SUBGENUS *TRUNCACILA* SCHENCK IN GRANT AND GALE

Truncacila Schenck MS., in Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 115, November 3, 1931. — Schenck, Geol. Soc. Amer., Spec. Papers No. 4, p. 23, 1936. "Genotype: *Nucula castrensis* Hinds, by original designation."

Type species (by original designation). — "Type: *Nucula castrensis* Hinds."

Range. — Cretaceous to Recent.

Description. — Adult shell seldom exceeds 30 millimeters in length; trigonal; quadrangular or ovate in outline; lacking the well-defined rostral sinus that characterizes *Acila, sensu stricto;* one or more bifurcations (divarications) of the radial ribs. (Schenck, 1936.)

Remarks. — Schenck listed 17 species and subspecies definitely referable to *Truncacila* and several others doubtfully belonging to this subgenus.

One species, the type of this subgenus, occurs in the San Diego formation.

Acila (Truncacila) castrensis Hinds
Plate 27, Figures 7, 8, 9, 10

Nucula castrensis Hinds, Proc. Zool. Soc. London for 1843, p. 98, issued December, 1843. — Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, p. 63, pl. 18, fig. 5, 1844 (January 1845 on cover of Pt. 3). — Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 204, 1909. Quillayute Formation, western Washington, Pliocene. Also "Purisima-San Diego" formation in California. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 182, 1912. "San Diego-Purisima." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, No. 1, p. 14, pl. 5, fig. 11; pl. 37, figs. 1, 2, 1924. Recent. Also "Pliocene" at "San Diego." — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 84, 1929. "San Diego Pliocene."

Acila lyallii Baird, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "Well at San Diego." — Dall, Proc. U. S. Nat. Mus., Vol. 1, No. 2, p. 28, 1878. "well-digging in stratum B^2," San Diego. — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, August, 1889 (as *Acila lyalli*). Dall's record (1874) cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper

446, p. 59, 1919 (as *Acila lyalli*). Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) cited.

Acila castrensis Hinds, Cooper, Calif. State Min. Bur., Seventh Ann. Report of State Mineral. Vol. 7, p. 227, 1888. "San Diego well, "Pliocene." — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Quotation of Dall's record (1874). — Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, 1941. "? Strata penetrated by well in San Diego."

Nucula (Acila) castrensis Hinds, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 95, 1903. Cooper's record (1888) cited from San Diego well. — Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 174, 1909. The record "San Diego (Cooper)". — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 116, pl. 1, figs. 6a, 6b (Recent), 1931. ?Miocene; Pliocene to Recent. Also "San Diego well, San Diego (Cooper)."

Acila (Truncacila) castrensis Hinds, Schenck, Geol. Soc. Amer., Spec. Papers No. 4, p. 96, pl. 10, figs. 1-5 (Recent), text fig. 7 (2-5), 1936. Pliocene to Recent. From San Diego Pliocene at "loc. 331 [SD], ravine 200 feet north of Mexican boundary, 3/4 mile east of coast," Pliocene.

Type specimen. — Present disposition unknown (according to Schenck).

Type locality. — "Hab. Sitka, North-west America. A single specimen was dredged in the harbour, from seven fathoms, sand." (Hinds.)

Range. — Pliocene to Recent. Recent, Sitka, Alaska, to Cedros Island, Lower California, Mexico, in 9 to 1280 meters (5 to 700 fathoms).

Occurrence in San Diego Fm. — Well at San Diego (Dall). C.A.S. 12099, 28889, 28892. L.A.M. 104, 107, 305. S.D. 331. U.C. A-8333. U.C.L.A. 294, 295, 309, 312, 2359.

Original description. — Nuc. testâ ellipticâ, anticè rotundatâ, epidermide olivaceâ indutâ; lineis divaricatis; marginibus ventralibus crenulatis; cardine anticè dentibus 5, posticè 11. Long. 3; lat. 1 1/2; alt. 2 lin. (Hinds.)

Remarks. — Three specimens of this posteriorly truncate species, one with both valves, and two single valves, are present in the Henry Hemphill collection of the California Academy of Sciences from the San Diego well. The largest specimen, a single valve, is approximately 9 mm long, 7.3 mm high, convexity, 2.4 mm. The shape and sculpture of these specimens are similar to that of specimens of comparable size now living in west American waters.

Over a hundred specimens of this species were collected by Kanakoff at Loc. 305 (LAM), near the United States-Mexico boundary. The largest valve is 11 mm long and 8.8 mm high. A cast from Loc. 104 (LAM), is 12.8 mm in length.

Schenck's careful study (1936) of *Acila castrensis* indicated that specimens occurring in the waters of southern California attain maximum lengths of about 12 mm, but that those occurring in the waters of Washington and Alaska may attain a length of 20 mm, and a height of 16 mm. He also mentioned that the anterior series of teeth may range to 24 in number and the posterior series to 12. The height in some specimens may range from 74 to 90 per cent of the length. Frizzell (37) published the results of a study of the variation in the sculpture of 358 specimens from Puget Sound. The soft parts of *A. castrensis* were studied by Heath (38).

Acila castrensis has been recorded from various localities in California in beds of Pliocene and of Pleistocene age. The records of its occurrence by Khomenko (39) in strata of late Tertiary age on the Schmidt Peninsula, Kamtschatka, and that of Simonova (40) from east Sakhalin, need confirmation.

FAMILY NUCULANIDAE H. AND A. ADAMS (41)

Shell similar to the Nuculidae but elongated, the posterior side longer, narrower, often rostrate, and partly gaping at the end; the anterior end shorter, more rounded and convex; hinge and ligament as in the Nuculidae, the resilium sometimes external or lacking; internal shell layer subnacreous in the early forms but mostly porcelaneous in more Recent forms; mantle lobes more or less united; with siphons; pallial line usually sinuated. Devonian to Recent.

Remarks. — Stenzel et al., 1957, placed this family under a Superfamily "Nuculanicae". McAllister, 1964, also favors assigning a superfamily ("Nuculanicea") to this group of mollusks.

Dell (42) cited about 90 names (some homonyms, synonyms, or unacceptable for various reasons) which have been proposed for supraspecific units of this family. Verrill and Bush (43) published a revision of the Nuculanidae of the Atlantic Coast of the United States.

Most of the Recent species of this family live on muddy bottoms.

Key to Genera of Nuculanidae

A. Shell closed (or nearly so) posteriorly; pallial sinus usually shallow . . . . . .*Nuculana*

B. Shell gaping posteriorly; pallial sinus usually deep . . . . . .*Yoldia*

GENUS *NUCULANA* LINK

Nuculana Link, Beschreib. Nat. — Samml. Univ. Rostock, Abt. 3, p. 155, May 17, 1807. Sole species: "*N. rostrata.*" Ref. to Gmelin, p. 3308, and to Chemnitz, Vol. 7, pl. 55, figs, 550, 551. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 118, 1931. "Type (by monotypy) *Arca rostrata* Chemnitz." — Hertlein and Strong, Zoologica, Vol. 25, Pt. 4, p. 390, 1940. "Type (by monotypy): *Arca rostrata* Chemnitz." — Cox, Mem. Geol. Surv. India, Palaeo. Indica, Ser. 9, Vol. 3, Pt. 3, p. 26, 1940. "Genotype: *Arca rostrata* Chemnitz."

Leda Schumacher, Essai Nouv. Syst. Test., pp. 55, 172, 173, 1817. Type indicated as *Arca rostrata* Chemnitz, illustrated by Schumacher on pl. 19, fig. 4.

Type species (by monotypy). — *Arca rostrata* Chemnitz [= *Mya pernula* Müller]. ["*Arca Martini rostrata*" Chemnitz, Neues Syst. Conchyl. — Cab., Bd. 7, p. 206, pl. 55, figs. 550, 551, 1784. "Sie werde schon ohnweit Helsingburg in einen Meerbusen bey Kullen, und noch haüfiger bey Norwegischen Stranden gefunden." —

Schenck, Bull. Mus. Roy. d'Hist. Nat. Belgique, Vol. 10, No. 20, pl. 1, fig. 2, 1934 (hinge of *Nuculana pernula* Müller). — Habe, Gen. Jap. Shells, Pelecypoda, No. 1, p. 24, 1951. Type species: *Arca rostrata* Bruguière. (Figs. 20, 21, *Nuculana pernula* Müller).]

Range. — Jurassic (perhaps Triassic) to Recent. Recent, world-wide, abundant in cool marine waters, 5 to 3658 meters (3 to 2000 fathoms).

Description. — Shell elongate, often somewhat crescent-shaped, usually rostrate and somewhat carinate posteriorly bounding an escutcheon; valves closed or gaping slightly at the posterior end; beaks small, opisthogyrate; sculpture consisting chiefly of concentric threads, more closely spaced toward the ventral margin; resilium on a small, triangular chondrophore, inclined posteriorly under the beaks and separating two series of teeth, the posterior series about twice as numerous as the anterior series; this arrangement of the resilium is present in Cenozoic forms but in some earlier groups it is nearly lacking and the ligament is entirely posterior to the beaks; pallial line sinuous in Recent forms but in some early forms it is only slightly or not sinuated.

Remarks. — About 20 species of this genus have been described from Tertiary strata in California and about 60 species have been recorded occurring in the marine waters of the western Americas between Bering Sea and Cape Horn. Only about four species have been recorded from beds of Pliocene age in western United States, one of which occurs in the San Diego formation.

Cox, 1940, discussed some of the Mesozoic *Nuculana*-like forms. He pointed out that many Jurassic species are referable to the genus *Nuculana* but that it is doubtful whether they are referable to Recent subgenera. Some of the Jurassic species possess nacreous shells and some species have an entire, not sinuated pallial line.

SUBGENUS *NUCULANA* S. S.

Nuculana (Nuculana) aff. *N. (N.) leonina* Dall

Plate 57, Figures 17, 20

The following references refer to typical *N. leonina*.

Leda leonina Dall, Nautilus, Vol. 10, No. 1, p. 2, May, 1896. "Off Sea Lion Rock, Coast of Washington in 477-559 fathoms, mud, U. S. Fish Commission." — Dall, Bull. Nat. Hist. Soc. Brit. Columbia, No. 2, p. 7, pl. 2, fig. 12, January, 1897. "dredged by the U. S. Fish Commission in the Straits of Fuca and off Sea Lion Rock on the coast of Washington, in 477-559 fathoms." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 21, pl. 13, fig. 18, 1924. Type locality cited. "Range. Strait of Juan de Fuca to latitude 36 north."

Occurrence in San Diego Fm. — L.A.M. 305A.

Remarks. — A right valve of a *Nuculana*, 8.6 mm long and 4.8 mm high, is present in the collections from near the Mexican boundary. The exterior sculpture is comprised of ten narrow, elevated ridges between which in some areas there are traces of minute concentric striae. A narrow shallow depression just below the dorsal posterior margin extends from near the beak to the posterior end of the valve.

The present specimen bears a general resemblance to *Nuculana leonina* Dall but is less rostrate, higher in proportion to the length, has much wider interspaces between the concentric ridges and fewer hinge teeth.

There is variation in the sculpture in a series of specimens of *N. leonina* but none that we have seen have nearly such wide interspaces between the concentric ridges and all have many more teeth on the hinge.

The present fossil probably represents an undescribed species, but because only one small valve which has undergone some erosion is available, we merely report its occurrence and call attention to its general similarity to *N. leonina*.

SUBGENUS *SACCELLA* WOODRING

Ledina Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, p. 53, December, 1898. "(Tipo *L. fragilis* (Chemnitz))". Not *Ledina* Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 580, April, 1898. "Type *L. eborea* Conr., 1860, not 1846, = *L. smirna* Dall, Eocene."

Saccella Woodring, Carnegie Inst. Washington, Publ. 366, p. 15, May 20, 1925. "Type (by original designation). — *Arca fragilis* Chemnitz (= *Leda commutata* Philippi)." — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. 3, p. 53, 1930. Type as indicated by Woodring. — Hertlein and Strong, Zoologica, Vol. 25, Pt. 4, p. 392, 1940. "Type (by original designation): *Arca fragilis* Chemnitz."

Type species (by original designation). — *Arca fragilis* Chemnitz [Neues Syst. Conchyl. -Cab., Bd. 7, p. 199, pl. 55, fig. 546, 1784. "Mittelländischen Meeres." — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 5 (Pelecypoda, Fasc. 18), p. 215, pl. 37, figs. 26-31, 1891 (= *Nucula commutata* Philippi). Mediterranean and east Atlantic. Miocene to Recent].

Range. — Paleocene (Midway) to Recent (Gardner, Bull. Amer. Assoc. Petrol. Geol., Vol. 25, No. 4, p. 647, 1941).

Description. — Shell small, high, slightly inequilateral, posterior end rostrate, rostrum sharply pointed and unicarinate; a shallow groove extends from the umbo to the ventral margin at both ends of the valve; sculpture consisting of strong concentric rugae; hinge like *Leda s. s.*, but the anterior and posterior series of teeth are approximately equal in length; apex of pallial sinus broadly U-shaped. (Woodring, 1925.)

Remarks. — The shell of *Saccella* differs from that of *Lembulus* Risso (44) in that it has concentric instead of diagonal sculpture and also it has a narrower and shallower posterior groove.

Another genus, *Jupiteria* Bellardi (45), type *Nucula concava* Bronn, has a hinge similar to that of *Saccella* but the shape of the shell is more like that of *Corbula* and the exterior bears very fine, regular, concentric sculpture.

Praesaccella Cox (46) described from beds of Jurassic age in India is said to differ from *Saccella* in that the pallial line lacks a sinus and the hinge teeth are larger and less numerous.

Mesosaccella Chavan (47), described from strata of late Cretaceous age in Europe, has an external ligament situated just posterior to the beaks. The series of teeth continue beneath the beaks where they are elevated. There is no well defined ligamental pit, the fossette is merely a vague triangular depression formed by an enlargement of the cardinal margin.

Nuculana (Saccella) taphria Dall
Plate 27, Figures 11-13, 16-18

Nucula caelata Hinds, Proc. Zool. Soc. London, p. 99, December, 1843. — Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, p. 64, pl. 18, fig. 13, 1844 (January 1845 on cover of Pt. 3).

Not *Nucula coelata* Conrad, Amer. Jour. Sci., Vol. 23, No. 2, p. 343, January, 1833. Claiborne, Alabama. London clay [Eocene].

Leda coelata Hinds, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, December, 1874. "well at San Diego." "Pliocene." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11 (well at San Diego), p. 28 ("well-digging in stratum B^2."), 1878. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 48, 1944. Dall's record (1874) cited.

Leda caelata Hinds, Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., Vol. 7, p. 245, 1888. "San Diego well." Pliocene. — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, August, 1889. Dall's record (1874) cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Orcutt's citation of Dall's record (1874).

Leda taphria Dall, Nautilus, Vol. 10, No. 6, p. 70, October, 1896. New name for *Nucula "coelata"* Hinds, 1843, not *Nucula coelata* Conrad, 1833. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 98, pl. 17, fig. 5 (lower San Pedro Series), 1903. "San Diego well (Cooper)" and "Pliocene of Pacific Beach". — Arnold, U. S. G. S., Prof. Paper 47, p. 28, 1906. "San Diego formation." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 172, 1912. "San Diego-Purisima." — Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Sci., Vol. 18, No. 3, table opp. p. 78, 1929. "San Diego Pliocene". Also other formations.

Nuculana taphria Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 121, pl. 1, fig. 8 (Holser Canyon, Pliocene), fig. 9 (near Goleta, California, Pleistocene), 1931. "San Diego formation of Reynard Way, San Diego," also record of Arnold (1906) and Cooper (1888) cited.

Saccella taphria Dall, Moore, San Diego Soc. Nat. Hist., Occ. Paper 15, p. 50, pl. 23, figs. e, f, g, 1968. Balboa Park; Pacific Beach, Pliocene. Also other localities. Also Miocene to Recent.

Type specimen. — Location unknown to the present authors. Originally in "Cab. Belcher." Not found in British Museum by Keen (Veliger, Vol. 8, No. 4, p. 267, 1966).

Type locality (of *Nucula caelata*). — "Hab. California, between 38° 18' and 34° 24' north latitude; namely, at Russian Bodegas, San Francisco, and Santa Barbara, in from six to ten fathoms."

Range. — Late Miocene (Briones); Pliocene to Recent. Recent from Bodega Bay, California, to Punta Arena, Lower California, in 5 to 93 meters (3 to 51 fathoms).

Occurrence in San Diego Fm. — Well at San Diego (Dall). C.A.S. 1400, 1401, 1402, 1404, 28889. L.A.M. 104, 107, 305, 305A, 305C, A1323. S.D. 29, 75, 80. U.C. A-8333. U.C.L.A. 294, 1386, 2359.

Original description of *Nucula caelata* Hinds. — Nuc. testâ luteo-virente, oblongâ, argutè sulcatâ; anticè arcuatè rostratâ, sulcis paululùm obliteratis; umbonibus prominulis. Long. 7; lat. 3; alt. 4 lin. (Hinds.)

Remarks. — The description attributed to Dall by I. S. Oldroyd, 1924, is from Arnold, 1903.

The umbos of *Nuculana taphria* are nearly centrally situated, the rostrum is bluntly pointed and the exterior is sculptured with well developed, uniform, sharp, raised, concentric ribbing. A narrow lunular area is present and there is a long, narrow escutcheon concentrically striated. A narrow, shallow, depressed area extending from the umbos to the ventral margin is usually present just anterior to the dorsal margin. There are two gently curved rows (the anterior slightly the longer) of chevron-shaped teeth, about 20 in each series. A shallow pallial sinus is present. A typical specimen from off San Martin Island, Lower California, is 18 mm long, 11.2 mm high, convexity (both valves together), 8.9 mm.

Heath (48) described the soft parts of this species.

We have examined over two hundred specimens, ranging from 3 to 22.6 mm in length, collected by George Kanakoff at Loc. 305 (LAM), near the Mexican boundary, and find variation fully as great as in a similar series of Recent shells. Larger shells tend to be more globose with the posterior end more pointed and upturned. Some of these have been bored on the umbo by a gastropod.

When Dall, 1896, proposed the new name, *Leda taphria* for *Nucula caelata* Hinds (*non* Conrad), he gave no description nor did he cite any type specimen.

Mrs. Ellen J. Moore, United States Geological Survey, examined specimens in the United States National Museum which were labelled *Nuculana taphria* by Dall, and furnished us information concerning them which we include here.

She stated (49) that a specimen, No. 122579 (USNM), 18 mm long, entered in the catalogue on July 25, 1891, was labelled by Dall "*Leda taphria* Dall, (Fig'd.), Sta. 3147, 56 fms., mud, 49.2°, off Pt. Año Nuevo, Cala." Another specimen, No. 107432 (USNM), 17.2 mm long, entered in the catalogue April 13, 1896, was labelled "*Leda caelata* Hinds, Fig'd., 56 fms., off Pt. Año Nuevo, Cala. USFC." In the vial with the specimen there is a printed slip by Dall, stating "Fig'd. type." This specimen compares favorably with the specimen illustrated by Dall in 1897 which he stated was 17 mm long. Furthermore, Mrs. Moore stated that neither of the specimens mentioned above were entered as types in the catalogue and both were in the general collection of mollusks.

It appears to us that Dall originally made a simple substitution of the name *taphria* for *caelata* Hinds and Dr. H. A. Rehder (50), United States National Museum, concurs in this opinion. We, therefore, consider the specimen illustrated as *Nucula caelata* by Hinds to be the type of *Nuculana taphria*.

The original figure by Hinds is 13 mm long. Compared with this the specimen illustrated by Dall, 1897, is more globose, slightly higher in proportion to the length and it is posteriorly slightly more concave and pointed. Through the courtesy of Dr. Harald Rehder, we were able to examine this specimen illustrated by Dall. The dimensions are approximately, length, 17.2 mm, height, 11.4 mm, convexity (both valves together), 9.2 mm. In view of the variation in this species, we are inclined to consider both illustrations as representing the same species.

The shell of this species is less elongate, more inflated, and the surface is less polished than that of *Nuculana callimene* Dall (51) from Panama and it has much coarser sculpture than that of *N. pontonia* Dall (52), originally described from the Galápagos Islands. The presence of an anterior lunular area on *N. taphria* serves to separate it from the similar *N. balboae* Brown and Pilsbry (53) from mid-Miocene strata of Panama. Furthermore, the Panamanian species has a much greater number of teeth, 28 in the anterior and 18 in the posterior series.

A species recently described as *Saccella calkinsi* by Moore (54) from the Astoria formation of middle Miocene age in Oregon, is said to differ from *N. (S.) taphria* in the less strongly recurved rostrum, narrower, longer escutcheon and narrower and less ovate lunule.

Nuculana taphria has been reported by some authors (55) as definitely identified from strata of late Miocene age but others (56) have cited it with doubt as "*Leda* cf. *taphria* Dall" from beds of similar age. Records of its occurrence in the later Tertiary of Kamtschatka (57) and in Sakhalin (58) may be open to question.

GENUS *YOLDIA* MÖLLER

Yoldia Möller, Naturhist. Tidsskrift, Bd. 4, No. 1, p. 91 (also separately, Index Moll. Groenlandiae, p. 18), 1842. Species cited: "*Y. arctica, Nucula arctica* Gray" and "*Y. angularis* nob., *Nuc. myalis* Couth.?" — Verrill and Bush, Proc. U. S. Nat. Mus., Vol. 20, No. 1139, p. 858, June, 1898. "Type. — *Yoldia hyperborea* Torrell = *Yoldia arctica* Möller (not Gray)." — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 59, 1930. Type designation of Verrill and Bush accepted. — Kanno, Jap. Soc. Promotion of Sci., Neno, Tokyo, p. 198, 1960. Type: *Nucula arctica* Möller.

Type species (designated by Verrill and Bush, 1898. Also by the Internatl. Comm. Zool. Nomencl., Opinion 769, Bull. Zool. Nomencl., Vol. 23, Pt. 1, p. 33, April 29, 1966). — "the nominal species *Yoldia hyperborea* Torell, 1859, is hereby designated to be the type-species of that genus." [*Yoldia hyperborea* Torell, Bidrag till Spitzbergens molluskfauna (Stockholm), pp. 149-150, tab. 2, figs, 6a, 6b, 1859. — Ockelmann, Medd. om Grønland, Bd. 107, No. 7, pl. 1, fig. 1; pl. 2, fig. 3, 1954. — Cowan, Veliger, Vol. 11, No. 1, p. 58, pl. 5, figs. 6 (Point Barrow, Alaska), 7 (Disco, Greenland), 1968.]

Range. — Late Cretaceous to Recent. Recent chiefly in boreal and temperate waters, 0 to 5303 meters (0 to 2900 fathoms).

Description. — Somewhat similar to *Nuculana* but with thinner, subovate shell, slightly rostrate, usually gaping posteriorly; exteriorly sculptured by growth lines on concentric striae; hinge consisting of two subequal series of small chevron-shaped teeth; resilium-pit large, symmetrically underlapping both rows of teeth; pallial sinus deep and wide, the apex broadly U-shaped. (Hertlein and Strong.)

Remarks. — The species of *Yoldia* are most abundant in boreal waters. In western North America 21 species have been reported living in waters between Bering Sea and San Diego, California, and about a dozen species have been reported in the region between Cedros Island, Lower California, Mexico, to southern Chile. Fourteen species have been reported from strata of Tertiary age in California, five of them in strata of Pliocene age in California and two in Oregon. The genus is here reported from the San Diego Formation for the first time.

Uozumi (59) discussed many of the Japanese fossil forms of *Yoldia* and Ocklemann (60) remarked on the relationships of various North Atlantic species of this genus.

SUBGENUS *KALAYOLDIA* GRANT AND GALE

Kalayoldia Grant and Gale, new section, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 128, November 3, 1931.

Type species (by original designation). — *Yoldia cooperii* Gabb.

Range. — Oligocene (Eugene formation), to Recent.

Original Description. — Like *Yoldia, s. s.*, but posterior dorsal margin of shell curved, concave upward, typically much shorter than anterior dorsal margin; posterior portion of valves rostrate, typically somewhat narrowed vertically; sculpture consisting of definite concentric riblets; hinge with a long, gently curved anterior row of teeth, separated by a relatively large, shallow, ovate ligamental pit from the very short, nearly straight posterior row of teeth; pallial sinus large and deep. (Grant and Gale.)

Remarks. — Six or seven species described from the late Cenozoic of western North America are referable to this subgenus. The single Recent species, the type species of this group, ranges from central California to northern Lower California, Mexico.

Yoldia (Kalayoldia) cf. *Y. (K.) cooperii* Gabb

The following references, type specimen, type locality, range and description, refer to typical *Y. cooperii*.

Yoldia cooperii Gabb, Proc. Calif. Acad. Nat. Sci., Vol. 3, p. 189, January, 1865. — Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 31 (in part), pl. 9, fig. 54 (as *Y. cooperi*), 1866. "picked up by Dr. Cooper on the beach at Santa Cruz." — Schenck and Keen, California Fossils for the Field Geologist (Stanford Univ.: Calif.), 1940, pp. 65, 69, 80 (pp. 67, 71, 82, ed. 1950), pl. 1, fig. 3; pl. 4, fig. 12. Halfmoon Bay, California, Recent.

Yoldia cooperi Gabb, Packard, Univ. Publ. Zool., Vol. 14, No. 2, p. 248, pl. 14, fig. 9, 1918. "dredged alive outside the Golden Gate, in 68 fathoms and on a bottom composed of dark green sand." — I. S. Oldroyd, Standford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 30, pl. 1, fig. 1; pl. 37, fig. 9, 1924. San Francisco Bay to San Diego, California. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 128, pl. 1, fig. 13; pl. 14, fig. 3, 1931. Halfmoon Bay, California, Recent. Also cited from late Miocene to Recent. — Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 68, pl. 32, figs. d, e, 1968. San Diego area, Pleistocene.

Not *Yoldia cooperii* Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 31 (in part), 1866. "Miocene, south of Martinez, and north of Walnut Creek, Contra Costa County." Referred to *Yoldia cooperii supramontereyensis* Arnold, by Stewart, Acad. Nat. Sci. Philadelphia, Spec. Paper No. 3, p. 63, pl. 15, fig. 2, 1930.

Type specimen. — No. 30, 613, Univ. of California

Department of Paleontology, Invertebrate Type Collection.

Type locality. — "A single left valve was found on the beach at Santa Cruz, Cal., by Dr. Cooper."

Range. — Middle Miocene ("cf.") to Recent. Recent from off Point Reyes, California, to Todos Santos Bay, Lower California, Mexico, in 9 to 124 meters (5 to 68 fathoms), usually in sand.

Occurrence in San Diego Fm. — L.A.M. 323.

Original description: Shell thin, somewhat compressed, very inequilateral, beaks placed about a third of the length from the anterior end, minute; anterior end narrow, sub-acuminate, posterior end broadly rounded; base most prominent just posterior to the middle of the shell; surface sculptured by numerous small concentric ribs, rarely dichotomous or anastomosing on the widest part of the shell; these ribs are flat and abruptly truncated on the side nearest the beak, giving the surface, under a glass, the appearance of an overlapping. Epidermis shining, olivaceous; internally a bluish white; muscular scars large, the anterior triangular, posterior a third the largest, broadly suboval. Long. 1.25, lat. 2.6, alt. .25 [inches]. (Gabb.) [A description also was given in the Latin language.]

Remarks. — Fragments of two fossil valves retaining the umbonal area, ligamental pit and several teeth, are present in the collection. The largest fragment is 4.8 mm long. These fragments agree well with the corresponding portions of the shell of *Yoldia cooperi*.

The large ligamental pit and hinge teeth evidently are part of large valves. The largest Recent specimen, a right valve, in the collections of the California Academy of Sciences, collected by Henry Hemphill at San Diego, is 52.6 mm long and 25.5 mm high. A large left valve from Loc. 92 (CAS), collected by Bruce Martin from beds of late Pleistocene age on Deadman Island, San Pedro, California, is 55 mm long and 28 mm high.

Compared to *Yoldia oregonensis* Conrad (62), described from strata believed to be of Oligocene age, the beaks of *Y. cooperii* are more posteriorly situated and the rostrum is shorter.

Yoldia supramontereyensis Arnold (63), described from beds of late Miocene age in California, is less attenuated posteriorly than typical *Y. cooperii*.

Yoldia cooperii tenuissima Clark (64), described from beds of late Oligocene or early Miocene age in central California, has the beak more anteriorly situated and a longer rostrum than *Y. cooperii*.

A fossil form described as *Yoldia cooperi ochotensis* Khomenko (65), from beds of Pliocene age on Sakhalin Island in the North Pacific, is referable to the subgenus *Cnestrium* Dall. Illustrations of it reveal the presence of oblique lines crossing the concentric sculpture. It obviously is not related to *Y. cooperii*. Kamada (66) pointed out that this also was true of specimens referred to *Y. c. ochotensis* by Otuka (67).

Another fossil form, "*Yoldia cooperi* Gabb var. *kovatschensis*" Slodkewitsch (68), was described from beds questionably of Oligocene age on Kamtschatka. The concentric sculpture was described as consisting only of fine concentric lines but lacking concentric ridges such as are present on *Y. cooperii*.

SUBCLASS PTERIOMOPHIA BEURLEN
ORDER EUTAXODONTIDA GROBBEN
SUPERFAMILY ARCACEA OKEN (69)
FAMILY ARCIDAE OKEN (70)

Shell equivalve, or nearly so, trapezoidal, subquadrate, or rounded, with the posterior side equal or longer; ligament exterior, attached to an area beneath and often on both sides of the beak; hinge with taxodont teeth in two similar series meeting below the beaks, the long dimension of the individual comb-like teeth approximately at right angles to the dorsal margin of the valves; pallial line generally distinct, without a sinus; muscle impressions nearly equal. (Grant and Gale, 1931). Middle Jurassic (71) to Recent. Recent, world-wide.

Abundant in shallow, tropic, subtropic and warm temperate marine waters, but two genera, *Senila* Gray and *Scaphula* Benson, occur in brackish water, the latter also occurs in fresh water. *Bathyarca* occurs at depths of 3658 meters (2000 fathoms).

Remarks. — Reinhart (72) published a very useful monograph of the fossil west American species of this family. The Recent species have been discussed by Maury (73) and by Hertlein and Strong (74), and a publication by Olsson (75) contains a discussion of the members of the Arcidae living in the tropical waters of Peru and Ecuador. A recent paper by Noda deals with the Cenozoic Arcidae of Japan (Sci. Repts. Tohoku Univ., Sendai, Second Ser. (Geol.), Vol. 38, No. 1, pp. 1-130, pls. 1-14, figs. 1-16 in text, October 10, 1966). The anatomy of the Arcidae is discussed in a paper by Heath (76).

Eleven species and subspecies of the Arcidae were recorded by Reinhart from strata of Pliocene age in California. Four species and subspecies occur in the San Diego Formation.

Key to Genera and Subgenera of Arcidae

A. Ligamental area extremely wide and almost flat . . . . . *Arca*

B. Ligamental area narrow and V-shaped

a. Inner margin strongly crenulated; ribs narrow, strap-like . . . . . *Anadara*

aa. Inner margin not crenulated or only faintly so; ribs thread-like, usually alternating in size

b. Ligamental grooves all extending anterior to the beak; hinge with a continuous series of teeth . . . . . *Barbatia*

bb. Ligamental grooves confined chiefly posterior to the beak; hinge of adult with an edentulous gape centrally . . . . . *Fugleria*

GENUS *ARCA* LINNAEUS

Arca Linnaeus, Syst. Nat., ed. 10, p. 693, 1758. Fifteen species cited including *Arca noae*. — Reinhart, Bull. Mus. Roy. d'Hist. Nat. Belgique, Tome 11, No. 13, p. 14, 1935. "Type species; *Arca noae* Linné. . . . ."

Navicula Blainville, Dict. Sci. Nat., Vol. 34, p. 319, 1825.

Type (by monotypy): *Arca noae* Linnaeus. — Iredale, Brit. Mus. (Nat. Hist.), Great Barrier Reef Exped. 1928-29. Sci. Repts., Vol. 5, No. 6, Moll. Pt. 1, p. 291, 1939. "Haplotype: *Arca noae* Linné."

Not *Navicula* Bory de Saint-Vincent, Dict. Class. Hist. Nat. Paris, Vol. 2, p. 128, 1822. [Diatomacea.]

Byssoarca Swainson, Zool. Illustr., Ser. 2, Vol. 3, expl. to pl. 118, 1832-1833, issued March, 1833. Species cited: "*Byssoarca zebra*" from the "West Indies" and "Jamaica", and "*B. noae.*" — Sowerby, Proc. Zool. Soc. London for 1833, p. 16, issued May 17, 1833. — Herrmannsen, Ind. Gen. Malacozoor, Vol. 1, p. 149, 1846. "Typus: *Arca Noae* Linn."

Type species (by designation of Internatl. Comm. Zool. Nomencl., Opinion 189, signed October 5, 1944, published July 26, 1945). — *Arca noae* Linnaeus, 1758 [Syst. Nat., ed. 10, p. 693, 1758. "Habitat in M. rubro, Mediterraneo, Indico." Ref. to "List. conch. 3. B.s.6.c.1. t.5."; "Rumph. mus. t. 44.f.P."; "Gault. test. t.87.f.H.I.", and others. Illustrated by Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Tome 2, Fasc. 5 (Pelecypoda, Fasc. 18), p. 174, pl. 30, figs. 1-5, (6, var.), 1891. Mediterranean region, Atlantic to Senegal and the Canary Islands. For a discussion of this species see Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 143-144, 1952].

Range. — Middle Jurassic to Recent. Reported from Eocene to Recent in western North America. Recent, worldwide in tropical and subtropical marine waters, but some species ranging into the boreal zone. Mostly in intertidal zone to shallow neritic zone, occasionally to a depth of 146 meters (80 fathoms) or deeper. *Arca tetragona* Poli reported from a depth of 2655 meters (1457 fathoms).

Description. — The Arcas typified by *A. noae* are equivalve, inequilateral transversely elongate, rudely quadrate, or oval, commonly irregular in outline, and gaping anteriorly. The beaks are prominent, placed well forward and separated by a wide cardinal area scarred with oblique discontinuous cartilage grooves. The radials that adorn the outer surface differ in prominence and spacing on different parts of the shell. The hinge is straight; the teeth are numerous, short, subequal, and transverse. The adductor impressions are distinct, the pallial line is simple, and the inner margins are smooth or feebly crenate at the extreme edge in harmony with the radial ornamentation of the exterior. (Gardner, U. S. G. S., Prof. Paper 199, p. 22, 1948.)

Remarks: *Arca s. s.* is here recorded for the first time from the San Diego formation.

Reinhart cited seven species from the Cenozoic of western North America. Three species now live in tropical and subtropical waters of the western Americas. One of these, *A. fernandezensis* Hertlein and Strong, was originally described from Juan Fernandez Island off Chile in 34° South Latitude. *Arca pacifica* Sowerby ranges north to the head of the Gulf of California and to Scammon Lagoon, 27° 54' North Latitude, on the Pacific Coast of Lower California. In the Japan Sea, one species of *Arca s. s.* ranges to 45° North Latitude.

SUBGENUS *ARCA* S. S.

Arca (Arca) sisquocensis Reinhart
Plate 27, Figures 26, 27, 31-33

Arca (Arca) sisquocensis Reinhart, Jour. Paleo., Vol. 11, No. 3, p. 182, pl. 28, figs. 1-3, April, 1937. — Reinhart, Geol. Soc. Amer., Spec. Papers No. 47, p. 25, pl. 2, figs. (holotype), 10, 11, 12, 1943. "From the Careaga formation, Pliocene, of Fugler Point, near Santa Maria, Calif." — Hall, Jour. Paleo., Vol. 38, No. 1, p. 88 (in text), pl. 22, figs. 1 and 2, 1964. "Santa Barbara Formation, Packards Hill, Santa Barbara, California. Plio-Pleistocene."

Arca sisquocensis Reinhart, Vedder, in Vedder and Norris, U. S. G. S., Prof. Paper 369, p. 46, 1963. Terrace on San Nicolas Island, "Pleistocene. — Valentine and Lipps, Jour. Paleo., Vol. 37, No. 6, pp. 1294, 1299, 1963. 250-foot terrace on central Anacapa Island, "Early Pleistocene (or late Pliocene) age".

Type specimen. — No. 1382, California Institute of Technology.

Type locality. — "Pliocene asphalt beds of Fugler Point, 7 1/2 miles southeast of Santa Maria, Santa Barbara County, California (type)." [Cebada member of the Careaga Formation (Woodring, 1950).]

Range. — Middle Pliocene to early Pleistocene.

Occurrence in San Diego Fm. — L.A.M. 305, 305A.

Original description (of holotype). — Small, well-preserved right valve, elongate in outline, moderately inflated, slightly inequilateral.

Profile. — Anterior margin evenly rounded; ventral margin straight, nearly parallel to hinge margin; posterior margin straight, forming acute angle where it intersects ventral margin, and meeting hinge margin at angle of 45°. Umbo located just anterior to center of shell, projecting slightly. An unusually sharp ridge extends from umbo to posterior ventral corner; above this ridge, shell is concave. A faint medial sulcus extends from byssal gape, upward a short distance toward umbo.

Sculpture. — About 40 radial ribs, with occasional small inter-ribs. On posterior slope, ribs are large and dichotomizing; elsewhere, simple and ornamented with closely-spaced nodes. The five anterior-most ribs are as large as the posterior ones, but do not dichotomize. Concentric growth-lines are not prominent, but two distinct concentric bands may be distinguished, and several less distinct ones. Ligamental area narrow in front of umbo, wide behind, these becoming noticeably excavated. About two right-angled, chevron-shaped grooves directly beneath umbo. Hinge straight, narrow, only slightly wider at extremities than at center; thirty-two teeth, small and granular at center, increasing regularly in size toward extremities of hinge; teeth converge ventrally, the anterior more sharply than the posterior. Muscle scars distinct, notable because of a raised flange bordering inner side of each scar, the posterior flange being the larger. (Such raised flanges are ordinarily not present on *Arca s. s.*, although they are present in *Striarca*, and in *Noetia* and *Trigonarca* a flange is developed on the inner side of the posterior muscle scar; these flanges are therefore of interest, and have been previously mentioned) (5) [footnote]. Inner margin of shell crenulated, especially at extremities. Narrow byssal gape near center. Pallial line simple; within this line, inner side of shell faintly striated by radial lines.

Dimensions of holotype (in mm): Length 15.4; height 7.6; convexity (right valve) 4. (Reinhart.)

Remarks. — 20 specimens of this species vary in preservation, and in size from 5 to 24 mm long. The notable difference observed in this series, which varies from Reinhart's description of the type specimen, is the presence of about seven ligamental grooves on the cardinal area of the largest specimen (a fragment which represents an individual probably 30 mm long). This larger number of grooves is, no doubt, a result of the greater size of this shell in comparison to the holotype which is 15.4 mm long.

Woodring (77) pointed out that "Adult shells of *A. sisquocensis* have a wider posterior slope than that of *A. kobeltiana*, the posterior ridge being more strongly curved." An earlier name for *Arca kobeltiana* Pilsbry (78) is *A. boucardi* Jousseaume (79), a species reported to range from early Miocene to Recent in Japan.

Arca (Arca) leptogrammica Hall (80), described from strata of late Miocene age in the Nipomo quadrangle, San Luis Obispo Co., California, was compared by its author with *A. sisquocensis* and *A. boucardi*. The type of *A. leptogrammica* is 56 mm long. It was described as much larger than *A. sisquocensis* and with finer radial ribs which are not beaded.

GENUS *ANADARA* GRAY

Anadara Gray, Proc. Zool. Soc. London for 1847, p. 198 (issued November, 1847). "*Arca antiquata*" indicated as type. — Cox, Rept. Palaeo. Zanzibar Protectorate, p. 34, September, 1927. "Type: —*A. antiquata* (Linné); original designation."

Diluvarca Woodring, Carnegie Inst. Washington, Publ. 366, p. 40, May 20, 1925. "Type. — *Arca diluvii* Lamarck." — Woodring, Carnegie Inst. Washington, Publ. 385, p. 18, footnote, 1928. "*Diluvarca* is supressed as a synonym of *Anadara*."

Type species (by original designation): *Arca antiquata* Linnaeus [Syst. Nat., ed. 10, p. 694, 1758. "Habitat in O. Americano." Illustrated by Hanley, Ipsa Linnaei Conchylia, pl. 4, fig. 3, 1855, and by Woodring, Carnegie Inst. Washington, Publ. 366, pl. 4, figs. 1, 2, 1925. See discussion by Dodge (Bull. Amer. Mus. Nat. Hist., Vol. 100, Art, 1, p. 149, 1952) who considers Reeve's figure of *Arca maculosa* (Conch. Icon., Vol. 2, *Arca*, sp. 24, pl. 4, fig. 24, 1844) to represent the true *A. antiquata* of Linnaeus].

Range. — ?Late Oligocene (81) to Recent. Recent in western North America from Cedros Island, Lower California, Mexico, to the Gulf of California and south to Paita, Peru, littoral zone to 128 meters (70 fathoms), but usually in less than 75 meters (41 fathoms).

Description. — Shell thick, equivalve, ovate or trapezoidal, gibbous, more or less inequilateral; valves closed along ventral margin; cardinal area of moderate width, with the greater part of its surface covered by the ligament, and usually, although not invariably, ornamented with a few chevron-shaped grooves; sculpture consisting of strong, narrow, flattened ribs separated by squarely-channelled interspaces; internal margins crenulated according to the external ribbing; hinge-teeth obscurely discontinuous just behind the umbones, those belonging to the anterior series being slightly longer than those of the posterior series where the two series meet; central teeth small, perpendicular to the hinge-margin, the teeth increasing in length laterally and becoming slightly oblique at each extremity. (Cox, 1927.)

Remarks. — *Anadara* has been confused with *Arca* by some workers, but definite designation of *Arca noae* Linnaeus as the type species of *Arca* clearly places *Anadara* in a different group.

Diluvarca described by Woodring was later suppressed by its author and considered to be referable to *Anadara*. Olsson (1961, p. 87), more recently, doubted that *Anadara s. s.* is represented in west American waters. He assigned six species living in the eastern Pacific to *Diluvarca* which he placed as a subgenus of *Anadara*.

Nineteen species and subspecies originally described from the late Cenozoic of western North America were referred to *Anadara* by Reinhart. A huge specimen 90 mm long was reported by Mandra (82) from strata of late Cenozoic age in Salinas Valley, California.

Four species of *Anadara* are known from strata of Pliocene age in California. One species and a subspecies occur in the San Diego Formation.

Iwasaki (83) recently discussed the species of *Anadara* of Tertiary age in Japan.

Key to Species of *Anadara* (84)

A. Viewed from above (both valves together), anterior end broadly rounded . . . . . *calcarea*

B. Viewed from above (both valves together), anterior end sharply pointed . . . . . *trilineata*

Anadara trilineata Conrad
Plate 28, Figures 1, 2, 3, 4, 6

Arca trilineata Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, No. 6, p. 314, dated December, 1856, but apparently issued subsequent to April 25, 1857. — Conrad, U. S. Pac. Railroad Expl., Vol. 6, Pt. 2, No. 2, p. 70, pl. 2, fig. 9, 1857. [Original reference and locality cited.] "Tertiary." Illustration reproduced by Slodkewitsch, Paleo. of USSR, Vol. 10, Pt. 3, Fasc. 19, Tertiary Pelecypoda from the Far East, Pt. 2, Acad. Sci. USSR Press (Moscow; Leningrad), pl. 11, fig. 5, see pp. 105, 214, 1938. — Arnold, U. S. G. S., Prof. Paper 47, p. 100, 1906. "Pacific Beach, near San Diego." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 170, 1912. "San Diego-Purisima." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 150, 1919. "San Diego." — "cf." Dall, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 62, 1919. "lower member of . . . section" in well in "South Las Choyas Valley." — Carson, Pan-Amer. Geol., Vol. 43, No. 4, p. 268, 1925. "San Diego fauna." — Hertlein and Grant, Calif. State Jour. Mines Geol., Rept. State Mineral., 35, p. 69, 1939. "higher beds" in section of Pliocene strata at Pacific Beach. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Refers to Dall's record (1874) of *Arca microdonta* from well at San Diego. — Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1955. "San Diego formation."

Arca microdonta Conrad, Dall, Proc. Calif. Acad. Sci.,

Vol. 5, p. 297, 1874. "well at San Diego." "Pliocene." — Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 28, 1878. "Well" at San Diego and "well-digging in stratum B^2." — Cooper, California State Min. Bur. Seventh Ann. Rept. State Mineral., Vol. 7, p. 229, 1888. "San Diego well." — Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 85, 1889. Dall's record (1874) cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) referred to *Arca trilineata.*

Not *Arca microdonta* Conrad, House Doc. 129, Projected Vol. 3, 33rd Congress, 1st session, p. 13, 1855. "Locality. — Tulare Valley ? Miocene."

Arca sulcicosta Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 31, pl. 9, figs. 53, 53a, 1866. "Found with *Dosinia Staleyi,* on Mark West Creek, Sonoma County, by Mr. V. S. Staley." [Pliocene.]

Not *Arca sulcicosta* Nyst, 1836.

Arca schizotoma Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 659, April, 1898. New name for *Arca sulcicosta* Gabb, 1866. Not *Arca sulcicosta* Nyst, 1836. — Dall, U. S. G. S., Prof. Paper 59, p. 111, 1909. "San Diego well." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 170, 1912. "San Diego-Purisima."

Arca (Scapharca) trilineata Conrad, Dall, U. S. G. S., Prof. Paper No. 59, pp. 110-111, 1909. "Pliocene of San Diego well (city park), H. Hemphill, U. S. Nat. Mus. 7934; also Homer Hamlin."

Arca (Arca) trilineata Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 139, pl. 2, fig. 1 (Shuman's Cut), fig. 4 (Elsmere Canyon), 1931. P. 140, "Pliocene of San Diego well (Hemphill and Hamlin, *fide* Dall, 1909)."

Arca (Anadara) trilineata Conrad, Hertlein and Grant, Calif. State Div. Mines, Calif. Jour. Min. Geol., Rept. 35 Calif. State Mineral., p. 70, 1939. "San Diego well." — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 57, 1944. "Pliocene strata at Pacific Beach." — Glibert and Van de Poel, Mém. Inst. Roy. Sci. Nat. Belgique, Deuxième Sér., Fasc. 77, p. 55, 1965. Reynard Way, San Diego, Pliocene (as *Anadara (s. s.) trilineata).*

Anadara trilineata Conrad, Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, 1941. "Strata at Pacific Beach." — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. San Diego Formation at Pacific Beach. Also Niguel Formation and others. — Milow and Ennis, 57th Ann. Mtg. Cordilleran Sec., Geol. Soc. Amer., Field Trip Guidebook, San Diego Co., p. 28, 1961. "San Diego formation".

Anadara (Anadara) trilineata subsp. *trilineata* Conrad, Reinhart, Geol. Soc. Amer., Spec. Papers No. 47, p. 57, pl. 5, fig. 9; pl. 6, figs. 1-3, 5, 7; pl. 7, fig. 1, 1943. P. 59, "Pliocene, San Diego well, Balboa Park, San Diego."

Anadara (Anadara) trilineata Conrad, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 36, pl. 16, figs. a, b, 1968. Reynard Way, San Diego, Pliocene. Also Pliocene of California, Oregon, and Washington.

Type specimen. — Location unknown to the present authors. No record of the holotype at the U. S. National Museum (see Reinhart, p. 58).

Type locality. — "Occurs with the preceding" [which refers to *Arca canalis* Conrad with the locality "Santa Barbara, Cal." "Middle Tertiary."].

Range: Late Miocene (Cierbo sandstone); early and middle Pliocene in California, Oregon and Washington.

Occurrence in San Diego Fm. — C.A.S. 1129, 1401, 1404, 1415, 1418, 12107, 28885, 28889, 28892, 28893, 36384. L.A.M. 104, 107, 302, 305, 305A, 305B. S.D. 29, 34, 38, 79, 80, 81, 331, 365, 416, 417, 2954. U.C. A-8333. U.C.L.A. 294, 295, 302, 310, 312, 2359.

Original description. — Trapezoidal, somewhat produced, inequilateral, ventricose; ribs 22-24, scarcely prominent, square, wider than the intervening spaces, ornamented with three impressed or four raised lines; disks concentrically wrinkled; summits prominent; beaks approximate. Length 3 inches. (Conrad.)

Remarks. — There is uncertainty concerning the locality from which the type of *Arca trilineata* Conrad originally came, and the whereabouts of the type specimen is unknown. It is generally accepted that this is the well known elongately subtrapezoidal species which occurs as a fossil in strata of Pliocene age in California. Woodring (85) gave an adequate discussion of the problem of the type locality and the identification of this species.

We have had a large number of specimens available for study including several hundred valves varying in length from 5 mm to 68 mm, which were collected by G. P. Kanakoff at Locs. 305 and 305A (LAM) near the Mexican Boundary. The umbos of many of the valves have been bored by a gastropod. A valve from Loc. 305B (LAM) is 79 mm long.

These specimens vary somewhat in proportion of length to height but all are decidedly longer than high. The number of ribs varies, usually from 25 to 28. This is in agreement with Addicott's observations on specimens of this species from the Merced formation in northern Santa Clara County, California. He stated (86) that most of those have 26, some with 24, and some with 28 ribs. The ribs on the anterior half of the shell are often deeply sulcated or almost bifid, those on the posterior half usually bear two, three, or occasionally four shallow grooves. The ribs usually begin to develop a medial sulcation after the shell attains a height of about 8 to 10 mm, occasionally earlier. The ribs are usually at least partially beaded.

An impression of the anterior end of a large *Anadara,* 73 mm long, collected by G. P. Kanakoff at Loc. 107 (LAM), end of Arroyo Drive in San Diego, is probably referable to *A. trilineata.* The end view from above is not broadly rounded as is that of *A. t. calcarea.*

Specimens from the San Diego well in the collections of the California Academy of Sciences labelled "*Arca microdonta* Conrad" by Henry Hemphill, are definitely referable to *A. trilineata* and *A. trilineata calcarea.* Possibly the unfigured fossils recorded by Whiteaves (87) under the name of *Arca microdonta* from beds of late Tertiary age on Graham Island, Queen Charlotte Islands, Canada, is referable to *A. trilineata.* Woodring (88) and Reinhart (1943, pp. 46-47, p. 6, figs. 9, 10) have given good discussions of *Arca microdonta* Conrad (89), a species originally reported to have been found in "Tulare Valley?." Blake who sent the fossil to Conrad cited the locality as "the hills of the Coast Mountains near the Tulares." Woodring (1938, p. 31; 1941, p. 89) sug-

gested that this description might be applied to Kettleman Hills but he believed it possible that the specimens were collected by Blake on the Atlantic coast of Panama. The type specimen, of which we have seen a cast, bears a close resemblance to *A. nobilis* Röding in Bolten (*A. deshayesii* Hanley), a Recent Floridan and West Indian species. More recently, Weaver (90) cited "*Anadara? microdonta* (Conrad)" from the Temblor Formation, middle Miocene, Santa Monica, California. The illustrations closely resemble those of *Anadara topangensis* Reinhart (1943, p. 10, figs. 13, 14) from the Topanga Formation, Miocene, Santa Monica Mountains, Los Angeles Co., California.

Reinhart (1943, p. 58) doubted the record of the occurrence of *Anadara trilineata* in the Empire Formation which is of Pliocene age at Coos Bay, Oregon. Specimens from those strata which we have seen appear to be identical with *A. trillineata* except that they have about 29 radial ribs. Reinhart did not recognize specimens referable to *A. trilineata* in beds of Miocene age, but Hall (91) identified one specimen with this species from the Cierbo Sandstone in the La Costa Valley quadrangle in west central California and Stanton (Jour. Paleo., Vol. 40, No. 1, p. 23, 1966) reported this species from the Castaic Formation.

The fewer ribs as well as their beaded ornamentation and the slender umbos are features which serve to separate *Anadara trilineata* from two somewhat similar Miocene species, *A. devincta* Conrad (92) and *A. montereyana* Osmont (93). The less convex valves and more sharply projecting umbos as well as the usually beaded character of the ribs are shell characters differing from those of *A. devincta montesanoana* Etherington (94).

Species from the Miocene and Pliocene of Japan have been recorded under the name of *Arca trilineata* but as pointed out by Reinhart (1943, pp. 59-60) those fossils possess more numerous radial ribs (32-33), and later they were referred to other species by Hatai and Nisiyama (95).

Anadara amicula Yokoyama (96) from the late Tertiary of Japan is a similar species. Kanno (97) included eight species from Japan in the *A. trilineata* group, occurring in strata from late Oligocene to Pliocene age.

Slodkewitsch (98) cited a species from the Pliocene Kavrana series in Kamtschatka under the name of *A. trilineata* but those records cannot be referred with certainty to that species. Krishtofovich (99) mentioned a fossil form which he cited as a subspecies of *A. trilineata* with 29 to 34 ribs occurring in strata of early Pliocene age in Sakhalin Island.

Anadara trilineata calcarea Grant and Gale
Plate 28, Figures 5, 7-10

Arca (Arca) trilineata Conrad variety *calcarea* Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 140, pl. 2, figs, 6a, 6b, November 3, 1931. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers, No. 56, p. 26, 1944. Records of Grant and Gale cited.

Arca (Anadara) trilineata subsp. *calcarea* Grant and Gale, Reinhart, Geol. Soc. Amer., Spec. Papers No. 47, p. 61, pl. 9, figs. 6, 7, 8, 1943. "Pliocene of San Diego, Calif." Type locality also cited.

Arca trilineata calcarea Grant and Gale, Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 59, 1944. "Near the Mexican Boundary about three-quarters of a mile from the sea."

Anadara trilineata Grant and Gale, Korobkov, Metodicheskoe Rukovodstvo po Tretichnym Molluskam Plastinchatozhabernye [Lamellibranchiata], (Leningrad), pl. 55, fig. 4, 1954. Copy of pl. 2, fig. 6a of Grant and Gale, 1931.

Anadara trilineata calcarea Grant and Gale, Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. San Diego Formation. Also Niguel Formation.

Type specimen. — Holotype No. 436, Department of Geology, Stanford University.

Type locality. — "San Diego well; Pliocene."

Range. — Middle Pliocene (100) of southern California.

Occurrence in San Diego Fm. — Well at San Diego (*Arca trilineata* Conrad in part, of Dall). C.A.S. 1401, 1418, 12107.

Original description. — Shell like that of typical *Arca trilineata* Conrad, but larger, much thicker, and with more numerous cardinal grooves. (Grant and Gale.)

Remarks. — Reinhart (1943, p. 61) has added the following pertinent remarks concerning this form: "In addition, when viewed from above, the anterior end of the shell of *A. trilineata calcarea* is bluntly pointed, differing from typical *A. trilineata*, which is sharply pointed. This blunt point was acquired at a late stage in the growth of the shell of *A. trilineata calcarea* as shown by the growth lines."

The differences between this subspecies and typical *Anadara trilineata* are mostly the result of the large size, thick shell and corresponding convexity of the valves. Reinhart pointed out that several normal but rather large specimens of *A. trilineata s. s.* were found at the type locality of the subspecies *A. t. calcarea.*

About a dozen large specimens, mostly single valves, are present in the collections at hand. They are characteristic of the subspecies and possess about 26-27 radial, sulcated ribs and about 6 or 7 chevron-shaped ligamental grooves. The largest valve, the anterior end incomplete, from Loc. 1401 (CAS), south slope of Mount Soledad, is 86.8 mm long, 70.8 mm high, convexity (one valve), 30.8 mm. One from the San Diego well measures, length 78 mm, height 66.5 mm, convexity (one valve), 24 mm.

Three valves, the largest one 83 mm long, from Loc. 2359 (UCLA), south slope of Mount Soledad, cited among the locality records of *Anadara trilineata*, clearly show the first stages of the rounding of the anterior end which characterizes *A. t calcarea.* However, these valves have not developed the extreme rounded anterior end typical of *A. t. calcarea.* A specimen 59 mm long, typical of *A. trilineata*, was collected at the same locality.

Grant and Gale recorded the subspecies *Anadara trilineata calcarea* from strata of mid-Pliocene age in the Santa Clara Valley in southern California. Richmond (101) later reported its occurrence on Burruel Point, northwestern Santa Ana Mountains, Orange County, California, about 50 feet above the base of the "Repetto (?)" Formation.

[*Anadara trilineata canalis* Conrad]

Arca canalis Conrad, Proc. Acad. Nat. Sci. Philadelphia,

Vol. 8, No. 6, p. 314, dated December, 1856, but apparently issued subsequent to April 25, 1857. "Santa Barbara, Cal." "Middle Tertiary." — Conrad, Pac. Rail Road Expl., Vol. 6, Geol. Rept. 2, p. 70, pl. 2, fig. 8, 1857. Same locality as originally cited. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 170, 1912. "San Diego-Purisima." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 150, 1919. "San Diego." "Pliocene."

Anadara (Anadara) trilineata subsp. *canalis* Conrad, Reinhart, Geol. Soc. Amer. Spec. Papers No. 47, p. 60, pl. 7, figs. 3, 4, 1943. "Purisima formation. Pliocene of Capitola, Santa Cruz Co., Calif." "Known definitely only from the Pliocene of California."

Remarks. — The only records of the occurrence of this subspecies in the San Diego Formation are those of J. P. Smith. No specimens of this form were recognized by us in any of the collections from the San Diego Formation.

The subspecies *Anadara trilineata canalis* differs from typical *A. trilineata* in that the length and height are nearly equal. Reinhart (1943, p. 60) has given a good discussion of this form. According to him, *A. t. canalis* occurs with typical *A. trilineata* at some localities but that at Capitola and in Kettleman Hills, California, typical *A. trilineata* apparently ranges somewhat higher stratigraphically than does the form *canalis*.

GENUS *BARBATIA* GRAY

Barbatia Gray, Synopsis of the Contents of the British Museum, ed. 42, p. 151, 1840; ed. 44, p. 81, 1842. [No species cited. See Iredale, Proc. Malacol. Soc. London, Vol. 10, Pt. 4, pp. 299, 303, 1913.] — Gray, Proc. Zool. Soc. London for 1847, p. 197. Type indicated as "*A. barbata.*" — Reinhart, Bull. Mus. Roy. d'Hist. Nat. Belgique, Vol. 11, No. 13, p. 20, August, 1935. Type designated by Gray.

Type species (by subsequent designation, Gray, 1847). — *Arca barbata* Linnaeus [Syst. Nat., ed. 10, p. 693, 1758. "Habitat in M. Mediterraneo." Illustrated by Reeve, Conch. Icon., Vol. 2, *Arca*, sp. 83, pl. 13, fig. 83, 1844. "Hab. Mediterranean and other seas of Europe." — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Tome 2, Fasc. 5 (Pelecypoda, Fasc. 18), p. 182, pl. 32, figs. 1-5 (typical), 6, 7, 8 (var.), 1891. Mediterranean Sea to Cape Verde Islands. For a discussion of this species see Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 144-145, 1952.]

Range. — Late Jurassic (Kimmeridgian (102) to Recent. Recent world-wide in tropical and subtropical waters, some members ranging into the warm temperate zone. From the littoral zone to 183 meters (100 fathoms). Occasionally deeper.

Description. — Shell of moderate size, not very thick, inequilateral, elongately elliptical to subquadrate in outline, a slight byssal gape at the ventral margin, beaks anterior to center or subcentral; cardinal margin narrow; ligament multivincular; sculpture consisting of radial (often somewhat irregular) threads crossed by concentric striae; exterior with a hairy (bearded) periostracum; teeth increase in obliquity from the center to the ends of the hinge; inner margin crenated or smooth.

Remarks. — *Barbata* differs from *Arca s. s.*, type *Arca noae* Linnaeus, in the usually rounded umbonal angle, in the prosogyral beaks, the narrower ligamental area, the more oblique teeth, and the slighter byssal gape.

Cucullaearca Conrad, according to Reinhart (103) is "characterized by a large byssal gape, a wide, grooved ligamental area which usually separates the anterior teeth widely from the posterior ones, a widened posterior end, and a fairly heavy shell."

Abarbatia Dall, Bartsch and Rehder (104), based on a Recent Hawaiian species, was described as "Like *Barbatia* in ligamental and hinge characters, but differing from it in not having the periostracum cut into fringes but smooth."

SUBGENUS *FUGLERIA* REINHART

Fugleria Reinhart, Jour. Paleo., Vol. 11, No. 3, p. 184, April, 1937.

Type species (by original designation). — "*Barbatia (Fugleria) pseudoillota* Reinhart, n. sp., from the Pliocene of Fugler Point." Pl. 28, figs. 6, 9, 10.

Range. — Middle Pliocene to Recent. Recent in tropical and subtropical waters.

Description. — The ligament of *Fugleria* is similar to that of *Acar*, being confined chiefly to the posterior of the beaks, but the hinge is different, the posterior teeth of *Fugleria* being only feebly developed or even totally absent, as in the type species. *Fugleria*, in addition, lacks the elevated scars and reticulate sculpture of *Acar*. (Reinhart, 1937).

Remarks. — This subgenus is here recorded from the San Diego Formation for the first time.

The ligamental grooves on *Barbarca* Dall, Bartsch, and Rehder (105), based upon a Hawaiian species, are somewhat similar to those on *Fugleria* and the hinge has a subumbonal edentulous area. Whether this Hawaiian group is closely related to *Fugleria* is unknown.

Didimacar Iredale (106) also bears a general resemblance to *Fugleria* in outline, ribbing, and ligamentary grooves. It differs in that the hinge does not have an edentulous area under the beaks, the muscle impressions lack flanges and the periostracum is described as thin and dark.

Barbatia (Fugleria) illota Sowerby
Plate 27, Figures 35, 36, 38, 39, 40

Byssoarca illota Sowerby, Proc. Zool. Soc. London for 1833, p. 18, issued May 17, 1833.

Arca illota Sowerby, Reeve, Conch. Icon., Vol. 2, *Arca*, sp. 78, pl. 12, fig. 78, 1844. "Hab. Gulf of Nicoiya, Central America (found under stones); Cuming."

Arca (Byssoarca) tabogensis C. B. Adams, Ann. Lyceum Nat. Hist. New York, Vol. 5, pp. 486, 545 (separate, pp. 263, 321), July, 1852. "Habitat. — Taboga and Panama; C.B.A.!" "Under stones at low water." — Turner, Occas. Papers on Moll., Dept. Moll., Harvard Univ., Vol. 2, No. 20, p. 90, pl. 19, figs. 7, 8, 1956. Original record cited.

Barbatia (Acar) illota Sowerby, Maury, Palaeontogr. Americana, Vol. 1, No. 4, p. 182 (20), pl. 30 (2), figs. 8, 14, 1922. "Panama (Newcomb coll.); Bucarn [Bucaru], Los Santos Province; and the northeast point of Viveros Island, Islas de las Perlas (Olsson coll.)". —

Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 54, pl. 1, fig. 6 1950. Cited from San Marcos Island, and Santa Inez Bay, Lower California, Pleistocene.

Barbatia (Fugleria) illota Sowerby, Rost, Allan Hancock Pac. Exped., Vol. 20, No. 2, p. 187, pl. 11, figs. 6-8, text figs. 83a-c, 1955. "Isla Angel de la Guarda, Gulf of California, to Lobitos, Peru"; intertidal zone attached to rocks, to a depth of 40 fathoms.

Fugleria illota Sowerby, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 83, pl. 6, figs. 1-1b, 1961. Gulf of California to northern Peru.

Type specimen. — British Museum (Natural History)?

Type locality. — "Hab in Americâ Centrali." "Found under stones in the Gulf of Nocoiyo." [Costa Rica.]

Range. — Middle Pliocene to Recent. Recent from Punta Peñasco, Sonora, Mexico, to Lobitos, Peru, and the Galápagos Islands, from intertidal zone, attached to rocks, to a depth of 73 meters (40 fathoms).

Occurrence in San Diego Fm. — C.A.S. 28893. L.A.M. 305, 305A.

Original description. — Byss. testâ ovatâ, albâ, radiatim costatâ, costis numerosis, decussatis; epidermide fuscâ, foliaceâ indutâ; latere antico breviore, rotundato, postico declivi; areâ ligamenti angustâ, brevi: long. 1.5, lat. 0.75, alt. 1, poll. (Sowerby.)

Remarks. — More than 100 specimens of a small arcid collected by Kanakoff at Loc. 305 (LAM) are here assigned to *Barbatia (Fugleria) illota.* These vary in length from 3 to 20 mm. The shape is somewhat variable. On small specimens teeth are present along the entire hinge but on large specimens the posterior portion of the hinge is devoid of teeth except for four or five at the end. As mentioned by Rost the teeth are striated. The ligamental grooves on small specimens are posterior to the beak, but larger specimens (35 mm long) have as many as seven ligamental grooves, the upper ones not extending beyond the beak but the three lower ones forming asymmetric angles extending anterior to the umbo. The largest Recent specimen which we have seen is from Loc. 31389 (CAS). It was collected by W. D. Clark at Venado Island, Panama, and is 39 mm long, 25 mm high, the convexity (both valves together), 18.6 mm.

The present species has been recorded from beds of Pleistocene age in the Gulf of California region as well as in Panama and in Ecuador. The present record is the first of its occurrence in beds of Pliocene age.

The records of Melvill and Standen (107) of the doubtful occurrence of this species in the Persian Gulf are referable to some other species.

Barbatia (Fugleria) pseudoillota Reinhart (108) described from Pliocene strata near Santa Maria in Santa Barbara County, California, is a very similar species. The type specimen, a right valve, is 33.5 mm long, 31 mm high, and the convexity is 9 mm. It was described as less elongate than *B. (F.) illota* with about seven granular teeth anteriorly but completely lacking teeth on the hinge posteriorly. Our observations on the hinge of adult Recent specimens of *B. (F.) illota* agree with those of Reinhart, Woodring, and Rost, namely: that although there is a long edentulous area in the subumbonal area there are a few teeth at the posterior end.

Perhaps a large series of *Barbatia (Fugleria) pseudoillota* may reveal specimens with teeth on the posterior end of the hinge but none of such have been reported.

Barbatia (Fugleria) tenera C. B. Adams (109), of which *B. balesi* Pilsbry and McLean (110) is a synonym, from the Floridan and Caribbean region is similar to *B. (F.) illota.* The fossils described as *Arca (Acar) millifilia* Dall (111) from "Pliocene of Shell Creek, Florida," and a varietal form *B. (A.) m. latrinidadis* Maury (112), from the "Pliocene" of "Matura", Trinidad, were compared by their authors with *B. (F.) illota.*

FAMILY GLYCYMERIDIDAE NEWTON (113)

Shell orbicular, subtrigonal or subquadrate, equilateral, valves closed; isomyarian, integripalliate; beaks usually orthogyrate, located nearly centrally or slightly to the posterior; ligament external, made up of chevron-shaped parts; hinge plate arched; teeth taxodont, absent or small and transverse at center, side teeth oblique or parallel to hinge, the larger ones chevron-shaped, internal ventral margin usually crenulated; exterior smooth or with radial ornamentation; shell material porcelaneous. (Adapted from Nicol, Jour. Paleo., Vol. 19, p. 616, 1945.) Cretaceous to Recent.

Remarks. — Bowden and Heppell (114) recently discussed the usage of the family names "Glycymeridae" and "Glycimeridae." The earliest valid usage of "Glycymeridae" for the present family is by Newton, 1916. Stenzel, Krause, and Twining (115), pointed out that the correct spelling for this name is Glycymerididae. The family name Glycimeridae attributed to Deshayes (116) ("Les Glycimerides.", vernacular) by Chenu and others is now synonymous with Hiatellidae Gray, 1824.

Nicol has contributed several papers dealing with this family. These include one dealing with the phylogeny (117) of the Glycymerididae, one summarizing the genera (118) and subgenera, and one dealing with distribution of living glycymerids. (119)

A paper by Báldi (120) deals with the species of *Glycymeris s. str.* of Oligocene and Miocene age in Europe.

GENUS *GLYCYMERIS* DA COSTA

Glycymeris Da Costa, Hist. Nat. Test. Brit., p. 168, 1778. Species cited: "*G. orbicularis,*" pl. 11, figs. 2, 2. In synonymy, "*Chama glycymeris* Bellon," reference to Lister, Hist. Conch., tab. 247, fig. 82. Also other references including Pennant, Brit. Zool., No. 58, tab. 58, fig. 58. "*Arca. Glycymeris. Orbicular.*"

Not *Glycymeris* Lamarck, 1799 (= *Panope* Ménard, 1807).

Axinaea Poli, Test. Utrius. Sicil., Vol. 1, p. 32, 1791. Sole species: *Arca pilosa* [Linnaeus]. Type (designated by Gray, Proc. Zool. Soc. London for 1847, p. 198): "*Arca pilosa.*" [Linnaeus.]

Axinaeoderma Poli, Test. Utrius. Sicil., Vol. 2, pp. 254, 260, 1795. "*Arca pilosa* Linn."

Pectunculus Lamarck, Mém. Soc. Hist. Nat. Paris, Vol. 1, p. 87, 1799. Sole species: "*Arca pectunculus.* Lin." See remarks by Dall, Proc. Malacol. Soc. London, Vol. 10, Pt. 3, pp. 255-256, 1912.

Not *Pectunculus* Da Costa, 1778. (In superfamily Veneracea).

Type species (by tautonomy). — *Chama glycymeris* Bellon [= *Arca glycymeris* Linnaeus, Syst. Nat., ed. 10,

p. 695, 1758. "Habitat ad insulam Garnsey." Illustrated by Reeve, Conch. Icon., Vol. 1, *Pectunculus*, pl. 3, figs. 12a-b, 1843. Coasts of Britain. For a discussion of this species, see Dodge, H., Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 157, 1952.]

Range. — Cretaceous to Recent. Recent, world-wide in warm and temperate marine waters (but not in Arctic and Antarctic), in 0-640 meters (0-350 fathoms), but usually in less than 110 meters (60 fathoms). One species reported from a depth of 1846 meters (1010 fathoms).

Description. — Shell suborbicular to subtrigonal in outline, slightly truncated posteriorly; cardinal area with chevron-shaped ligamental grooves; hinge curved, set with transverse teeth which are larger and more horizontal toward the outer margins; gradual subsidence of ligamental area during growth results in progressive obliteration of teeth along dorsal margin; posterior adductor impression with a slight flange.

Remarks. — The usage by various authors of the names *Glycymeris* and *Pectunculus* was discussed by Chavan (121). He also discussed (122) the muscular impressions of *Glycymeris*.

The genus *Glycymeris* apparently reached its greatest development in number and distribution of species during Miocene time. A number of species have been described from Tertiary strata of California but only two are known to occur in the San Diego Formation.

About 100 species of *Glycymeris (sensu lato)* live in tropical, subtropical and temperate waters, frequently on sand or on a sandy, muddy bottom. Fifteen species and subspecies have been described from west American waters.

SUBGENUS AXINOLA N. SUBGEN.

Type species. — *Axinaea* (*?septentrionalis*, var.) *subobsoleta* Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 627, 644, August, 1864. (Reprint in Smithsonian Misc. Coll., No. 252, pp. 113, 130, 1872). Cited from Oregon; region between San Diego and San Pedro, California; islands off the coast of California; Vancouver, British Columbia. — Carpenter, Ann. Mag. Nat. Hist., Ser. 3, Vol. 14 (Nos. 5-37), p. 425, December, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 237, 1852. "Hab. Neeah Bay (Swan); Shoalwater Bay (Cooper)." For a discussion and illustration of this species see K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 63, pl. 1, figs. 8-10, 1958. "Recent. Neah Bay, Washington (type)."

Range. — Late Eocene to Recent. Recent from Lower California, Mexico, to Japan.

Description. — Shell small to moderate size (5 to 50 mm long), subtrigonal to suborbicular in outline, often produced posteriorly, convexity of valves slight, thin, sometimes chalky, the Recent species covered with a velvety periostracum; the exterior is smooth or with faint rather narrow, flat-topped radial ribs which become strongly accentuated by erosion; beaks usually opisthogyrate but in some species orthogyrate; cardinal area short, high, with ligamentary grooves forming asymetrical triangles, the anterior side the longer; hinge arcuate, the central teeth much finer than those at either end or sometimes nearly obsolete; interior ventral margin of valves crenulated, the crenulations with blunt ends.

Remarks. — At the time that the senior author and A. M. Strong studied the tropical west American species of *Glycymeris* it became evident to us that a group of species typified by *G. subobsoleta*, differed in shell characters from any described supraspecific unit. Later Dr. David Nicol came to the same conclusion during his study of the family Glycymeridae. The group of species, both Recent and fossil, here included in *Axinola*, appear to be confined to the borders of the northeastern Pacific region.

The combination of shell characters including the outline and the narrow, high cardinal area with decidedly asymmetrical ligamental grooves, and fine sculpture of the exterior differentiate *Axinola* from such groups as *Veletuceta* Iredale (123) and *Glycymerula* Finlay and Marwick (124).

The identification of the species in this group is fraught with difficulty. Willett (1944, p. 108) pointed out that this is caused by "the great amount of individual variation within the species. This applies not only to the shape, color and sculpture, but to the number of teeth, width of hinge-plate, width of ligamental area, and size and prominence of the umbos. Also there may be considerable morphological change between juvenility and maturity. There is often more similarity between the young of different species than there is between the adults; therefore, many young specimens are very difficult, if not impossible to identify."

Key to Species of *Axinola*

A. Umbos high, prominent;
apical angle 83° to 88° . . . . . *profunda*

B. Umbos low, often flattened;
apical angle 93° to 106° . . . . . *grewingki*

Glycymeris (Axinola) grewingki Dall
Plate 27, Figures 14, 19, 22, 24

Glycymeris grewingki Dall, U. S. G. S., Prof. Paper 59, p. 107, pl. 2, fig. 13, April 2, 1909. — Stewart, in Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, p. 90, pl. 29, figs. 10, 11; pl. 33, figs. 7, 8, issued June 7, 1941. "Etchegoin formation of North Dome," Kettleman Hills. — Weaver, Univ. Washington Publ. Geol., Vol. 5, Pt. 1, p. 62, pl. 10, fig. 19, 1942 (issued December 31, 1943). (Holotype.)

Glycymeris coalingensis Arnold, U. S. G. S., Bull. 396, p. 80, pl. 19, fig. 3, 1909 (issued January 10, 1910). Loc. 4806 (U. S. G. S.), "*Glycymeris* bed on north side Alcalde Canyon, 2 miles northeast of Alcalde, center of SW. 1/4 sec. 7, T. 21 S., R. 15 E." [M.D.B.M.] Coalinga district, California." "Etchegoin formation, upper Miocene." [Pliocene.] — Arnold, in Eldridge and Arnold, U. S. G. S., Bull. 398, p. 131, pl. 41, fig. 3, 1910. (Holotype.) — Clark, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 8, No. 22, checklist opposite p. 400, pl. 48, figs. 9, 10, 1914. Upper and Lower San Pablo, late Miocene. — Slodkewitsch, Acad. Sci. USSR, Paleo. Inst., Paleo. USSR, Vol. 10, Pt. 3, Fasc. 18, p. 137; Fasc. 19, pp. 104, 212, pl. 9, fig. 4, 1938. (Copy of Arnold's pl. 41, fig. 3.) — Hall, Univ. Calif. Publ. Geol.

Sci., Vol. 34, No. 1, p. 50, pl. 1, figs. 1, 2, 3, 4, 1958. Oursan Formation, Pleasanton area, California, middle Miocene.

Type specimen. — No. 107784, United States National Museum.

Type Locality. — "Miocene of Coos Bay, Oregon." [Pliocene.]

Range. — Middle Miocene (Oursan Formation) to middle Pliocene.

Occurrence in San Diego Fm. — C.A.S. 1400. L.A.M. 305. S.D. 4, 150. U.C.L.A. 1386. S.D.S.C. 32, 223.

Original description. — Shell solid, suborbicular, subequilateral, equivalve; beaks prominent, moderately convex, slightly separated by the area, which is narrow, in each valve forming a wide, very obtuse triangle with deeply incised angular sulci, radiating from the vertical of the beak; anterior slope slightly shorter and more rounded than the posterior, which is somewhat produced toward the lower portion; there is no distinct lunule or escutcheon; but a feebly differentiated anterior dorsal area is characterized by radial threads much finer than those on the anterior half of the disk; on the latter are about a dozen flat, little-elevated, radial ribs, separated by much narrower, channeled sulci, the whole with more or less obsolete fine radial striation; these radial ribs are distinct when the surface of the shell is intact; the anterior half of the disk, except when decorticated, nearly smooth except for close-set uniform numerous radial threads which cover the entire surface; when decorticated the internal structure shows ribs much like those normally exposed on the anterior half of the disk. Altitude of figured specimen, 38 mm; longitude, 38 mm; diameter 20 mm. (Dall.)

Remarks. — A few specimens from the San Diego Formation are flatter and more rounded than those of typical *G. profunda.* The umbos do not curve over the cardinal area which bears finer ligamental grooves and the apical angle is about 100°. These resemble *G. grewingki* Dall, especially those specimens illustrated by Stewart from late Pliocene strata on North Dome, Kettleman Hills, California. Some of the larger, more rounded specimens of *G. grewingki* illustrated by Stewart (pl. 33, figs. 7, 8) have an apical angle of about 120°. *Glycymeris coalingensis* Arnold is a synonym. Stewart stated (1941, p. 90) ". . . the differences between *G. coalingensis* and *G. grewingki* cited by Arnold being due to differences in the state of preservation of the type specimens." Large specimens from the coalinga area are 41 mm high.

Stewart suggested the possibility that some of the specimens from Kettleman Hills which he identified as *G. grewingki* might be a flat variety of *G. profunda.* The relationship of *G. grewingki* with the Recent forms described by Dall from southern California is not known.

The present specimens differ from *G. subobsoleta* Carpenter (125), a Recent species, in the higher umbos and correspondingly wider (dorsal-ventral) ligamental area and less prolongation posteriorly.

Willett pointed out that representatives of *Glycymeris subobsoleta* Carpenter in southern California often lack or nearly lack posterior elongation and the apical angle is about 90°. Presumably those southern shells would be referable to *G. corteziana* Dall (126) as interpreted by Woodring, Bramlette, and Kew, who gave the range of *G. subobsoleta* as Alaska to Oregon and that of *G. corteziana* (considered to be a southern race of *G. subobsoleta*) as Forrester Island, Alaska, to Magdalena Bay, Lower California. They considered *G. migueliana* Dall (127) to be a synonym of *G. corteziana.*

The present flattish specimens bear considerable resemblance to *G. migueliana* Dall and its probable synonym *G. corteziana* Dall, the types of which were illustrated by Willett. The name *G. migueliana* has line priority over the name *G. corteziana* on the page containing the original description. Whatever the relationship may be the names *Glycymeris subobsoleta, G. profunda, G. grewingki* and *G. coalingensis* all have priority over *G. migueliana* and *G. corteziana.*

Glycymeris vancouverensis Clark and Arnold (128), another member of this group described from the Sooke Formation on Vancouver Island, British Columbia, of late Oligocene or early Miocene age, was said to be closely related to *G. migueliana* but higher in proportion to the length and with a smaller apical angle.

Slodkewitsch (1938, pp. 104, 212, pl. 9, figs. 5, 5a) cited a species under the name of *Glycymeris coalingensis* from beds of Pliocene age in Kamtschatka but we have not seen specimens from that region.

Glycymeris (Axinola) profunda Dall
Plate 27, Figures 15, 20, 21, 23, 25, 28, 29, 30, 34, 37

Axinea profunda Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 13, July 1, 1878. — Schuchert et alii, U. S. Nat. Mus., Bull. 53, Pt. 1, p. 86, 1905. "Pliocene, San Diego, California." [Pleistocene.] — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 31, 1944. Earlier records cited.

Glycymeris septentrionalis [Middendorff], Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 82, 1929. "San Diego Pliocene."

Not *Pectunculus septentrionalis* Middendorff, 1849 [= *Glycymeris multicostata* Sowerby, 1833 (see Hertlein and Strong, Zoologica, Vol. 28, Pt. 3, No. 19, p. 151, 1943)].

Glycimeris profunda Dall, Willett, Bull. South. Calif. Acad. Sci., Vol. 42, Pt. 3, p. 111, pl. 11, figs. 3, 3a, September-December, 1943 (issued January 15, 1944). "taken in 200 fathoms off Santa Catalina Island," and "in 25 fathoms off Redondo, Los Angeles County." "Common in some Lower Pleistocene deposits, particularly so at Hill Top Quarry, San Pedro."

Glycymeris profunda Dall, Woodring, Bramlette, and Kew, U. S. G. S., Prof. Paper 207, p. 79, pl. 30, figs. 5-8, 1946. "Lomita Marl" at "Hilltop Quarry," also in "San Pedro sand," early Pleistocene.

Type specimen. — Lectotype from type lot No. 7935, United States National Museum.

Type locality. — Indicated as from "San Diego" (p. 11). On p. 29, cited from "recent alluvial soil, eight or ten feet above tide-water, is another stratum (D), in which the specimens are in a poor state of preservation." [According to Woodring, Bramlette, and Kew (1946, p. 79), "The type material was collected evidently from the Pleistocene strata overlying the Pliocene San Diego formation at Pacific Beach."]

Range. — Middle Pliocene to Recent. Recent from off Redondo and off Catalina Island, California, in 46 to 366 meters (25 to 200 fathoms).

Occurrence in San Diego Fm. — C.A.S. 28886. L.A.M. 124, 302, 305, 305A. S.D.S.C. 223.

Original description. — Shell subtriangular, ventral margin rounded, umbos erect, rather small. Area narrow, deep; marked by five or six lines meeting at an angle in the verticle of the umbo, one above another; anterior lines somewhat the shortest; exterior marked by twenty-five or thirty flattened ribs, separated by deep channels one-fourth as wide as the ribs, and by which the interior margin is crenulated. The ribs are crossed by thread-like close lines of growth, which may be elevated or obsolete on the ribs, but are sharply defined in the channels, which they partially fill up in some specimens. Toward the anterior and posterior margins, the sculpture is nearly obsolete. In eroded examples, this sculpture may be entirely altered, and such are hardly recognizable as the same thing. Interior smooth or lightly radiately striate, with a tendency to an elevated narrow ridge behind the anterior scar; hinge with teeth placed as if radiating from the centre of the valve, six to nine anteriorly, and ten to fourteen posteriorly, with some ten or twelve small, crowded teeth between the two radiating sets, and placed perpendicularly and parallel with one another. Height, 32 mm; length, 30 mm; thickness, 20 mm; the last proportionally greater in the young. (Dall.)

Remarks. — *Glycymeris profunda* is represented in collections from the San Diego formation from several localities, the largest number from Loc. 305 (LAM) near the Mexican boundary. There are over two hundred specimens from that locality varying in size from about 4 to 28 mm in height.

These specimens are high, thick, rounded trigonal, convex valves with high prominent umbos, the beaks curving over the rather wide (dorsal-ventral) cardinal area. The ligamental grooves are asymmetrical and on the more globose specimens rather coarse. The exterior of the shell is smooth when the preservation is perfect. Usually, however, removal of the outer layer by erosion exposes radial ribbing. Some of the globose valves agree almost exactly with specimens from the Pleistocene at Pacific Beach, part of the original lot of *Glycymeris profunda* which bear numbers 696 and 696a (see plate 27, figs. 15, 23, 28, 29) in the type collection of the Department of Paleontology of the California Academy of Sciences. One of the larger specimens in that lot is 23 mm long, 23.4 mm high, convexity (one valve), 9.3 mm, apical angle about 100^{0}. The arcuate hinge bears about 22 teeth. Many of the specimens in the present collections agree with the illustrations of *G. profunda* from beds of Pleistocene age in the San Pedro region, published by Woodring, Bramlette, and Kew.

Arnold (129) illustrated two specimens from the Pleistocene of San Pedro, one cited as *G. barbarensis* Conrad (fig. 9) and one as *G. septentrionalis* Middendorff (fig. 10). Willett considered both of these to be referable to *G. profunda*. Woodring, Bramlette, and Kew stated that Arnold's figure nine was similar to but of less height than typical *G. profunda*. Most of the specimens in the present collections from San Diego bear a similarity to Arnold's figure nine, but some, especially the flatter, higher ones, are similar to his figure 10. Judging from the variation in the globosity, height, and character of the ligamental grooves revealed in the series of specimens at hand, support is given to Willett's suggestion that both of Arnold's figures may be referable to *G. profunda*.

The identification of *Glycymeris barbarensis* Conrad (130) described over a century ago is involved in nomenclatorial problems because two different species were described under that name. No locality was cited by Conrad for the species illustrated in volume 6 of the Pacific Railroad Reports except that the title refers to "Tertiary Fossils" and in the text "California fossils", which Conrad believed "appear to represent the Miocene period" (131). The specific name would imply that it was believed to have been found in the Santa Barbara region. Woodring, Bramlette, and Kew ventured the opinion that the fossil, presumably of Pleistocene age, illustrated by Conrad is a possible synonym of the Recent *G. subobsoleta* Carpenter. Whatever the identification of *G. barbarensis*, it definitely appears to be distinct from typical *G. profunda*. According to Woodring, Bramlette, and Kew, the species cited under the name of *Axinaea barbarensis* in volume 7 of the Pacific Railroad Reports is probably referable to *Glycymeris veatchii* Gabb.

Glycymeris subobsoleta Carpenter (see K. V. W. Palmer, 1958, p. 63, pl. 1, figs. 8-10) has a thin shell which is elongated posteriorly and has a narrow cardinal area. The shell characters of some young specimens of *G. profunda* approach those of *G. subobsoleta* and *G. grewingki*.

Glycymeris tenuimbricata Clark (132), a species with high slender umbos, from the San Ramon beds of late Oligocene or early Miocene age, has an apical angle of about 90^{0} and bears a general resemblance to some specimens of *G. profunda*, but it has a much narrower cardinal area.

Glycymeris keenae Willett (133) from Alaska was described as a small (13.5 mm long) white shell with concentric sculpture and an angular hinge plate. Its general features are similar to those of *G. profunda* and allied species.

In addition to the occurrences at San Diego and San Pedro, California, *G. profunda* has been reported (the identifications mostly doubtful) from beds of Pleistocene age from Cayucos, California, to northern Lower California.

ORDER DYSODONTIDA NEUMAYR (FISCHER)
SUPERFAMILY MYTILACEA RAFINESQUE (134)
FAMILY MYTILIDAE RAFINESQUE (135)

Shell elongately ovate, bullet to wedge-shaped, often with an oblique axis, the valves equal. Beaks small, prosogyrate, placed usually near the anterior end, the umbonal slope posteriorly, often prominent and vaulted. Hinge line posterior of the beaks usually straight, plain or with a crenulated margin in harmony with a ribbed external sculpture, edentulous, or with small dysodont teeth on the anterior lunular margin below the beaks. Ligament subinternal, attached to an elongated calcified resilifer, usually white in color, compact or with pitted or cellular basal foundation. Typically dimyarian, the anterior adductor scar is always much smaller than the other and sometimes wholly eliminated in the adult, hence the posterior adductor scar is large and sometimes confluent with that of the posterior retractor. Surface smooth or with radial riblets; the sculpture is usually much stronger on the posterior-dorsal side, finer on the ventral side of the umbonal slope. Inner layer of the shell

is ordinarily nacreous, the outer layer thinner, darker, and covered by a thin or heavy, yellow, brown, green or black periostracum, hairy or bristly, often peeling off from dead valves. Marine, brackish to freshwater. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York, pp. 110-111, 1961.) Devonian to Recent.

Remarks. — The members of this family are often attached by a byssus or, as mentioned by Tryon, they frequently conceal themselves by spinning a byssal nest of sand and shell fragments, or they live in the burrows of other mollusks, or they burrow into soft substances.

Newell (136) discussed members of this family occurring in the late Paleozoic and Cox (137) remarked on the derivation of some of the genera in the Mesozoic Era.

A monograph by Soot-Ryen (138) dealing with the Recent west American species of this family appeared in 1955. He recognized 56 species which he distributed in 23 genera and 6 subgenera.

This family is represented in the San Diego formation by seven genera.

Key to Genera of Mytilidae

A. Sculpture divided into three distinct areas . . . . . *Gregariella*

B. Sculpture not divided into three areas; or smooth

a. Beaks terminal or nearly so; teeth on anterior portion of hinge

b. Interior with a small, triangular septum under the beaks . . . . . *Septifer*

bb. Interior lacking septum under the beaks

c. Shell usually not exceeding 3.5 mm in length; ovate with fine, even, radial sculpture . . . . . *Crenella*

cc. Shell exceeding 3.5 mm in length; often elongated or cuneiform

d. Margin strongly crenellated posterior to the ligament; radial sculpture coarse on dorsal, fine on ventral area. *Acidimytilus*

dd. Margin posterior to the ligament smooth; exterior smooth or occasionally with radial sculpture . . . . . *Mytilus*

aa. Beaks not terminal; teeth lacking on anterior portion of hinge

c. Shell obliquely oblong . . . . . *Modiolus*

cc. Shell subcylindrical . . . . . *Lithophaga*

GENUS *MYTILUS* LINNAEUS

Mytilus Linnaeus, Syst. Nat., ed. 10, p. 704, 1758. Seventeen species cited including *Mytilus edulis*. — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 95, 1930. Anton's designation of *Mytilus edulis* as type accepted. — Cox, Mem. Geol. Surv. India, Palaeo. Indica, Ser. 9, Vol. 3, Pt. 3, p. 74, 1940. "Genotype. — *Mytilus edulis* Linné (1758, p. 705), Recent, European Seas."

Type species (designated by Anton, Verzeich. Conchyl., p. 17, 1839). — *Mytilus edulis* Linnaeus. *Mytilus* with *M. edulis* designated as type by Anton was placed on the Official List of Genera by the Internatl. Comm. Zool. Nomencl., Opinion 94, in 1926. [*Mytilus edulis* Linnaeus, Syst. Nat., ed. 10, p. 705, 1758. "Habitat in O. Europaeo, Indico & M. Balthico". Ref. to Lister, Conch., 3, t. 362, fig. 20; Gualtieri, Test., t. 91, fig. E; also others. — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 4, p. 136, pl. 26, figs. 1-4, 1890. Mediterranean region, Black Sea, and England.]

Range. — Jurassic to Recent. Recent, world wide, from the intertidal zone to about 91 meters (50 fathoms).

Description. — Shell elongated and with terminal or subterminal pointed beaks; a thin nacreous layer present; valves with ventral margin nearly straight but wider and rounded posteriorly, gaping slightly for a byssus; smooth or radially sculptured; periostracum conspicuous; a few small teeth on a very small plate beneath the beaks or edentulous (lacking in some Mesozoic forms); anterior adductor impression small or lacking, high in umbonal cavity; posterior adductor impression larger, bilobed; pallial line not parallel to margin of valves.

Remarks. — Most species of the Mytilidae in the Cenozoic are readily referable to *Mytilus* or *Modiolus*. Among the Mesozoic forms, as pointed out by Cox (1940, p. 75), the differences in shell characters between the two are less distinct and there are fossil as well as Recent forms whose shell characters are intermediate between the two genera. The same author mentioned that from present knowledge of fossil forms of this group it appears that *Mytilus* descended from *Modiolus*.

Three species of *Mytilus* have been recorded as occurring in strata of Pliocene age in California, two of which have been reported from the San Diego formation.

Key to Subgenera of *Mytilus*

A. Anterior adductor impression small and shallow: anterior ventral margin smooth . . . . . *Mytilus s. s.*

B. Anterior adductor impression large and deep; anterior ventral margin minutely crenulated . . . . *Crenomytilus*

[SUBGENUS *MYTILUS* S. S.]
[*Mytilus edulis* Linnaeus]

Mytilus edulis Linnaeus, Syst. Nat., ed. 10, p. 705, 1758. [*Mytilus edulis* was placed on the Official List of specific names in Zoology by the Internatl. Comm. Zool. Nomencl. in Opinion 333, signed July 8, 1954, published February 23, 1955.] — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 66, pl. 27, fig. 4, 1924. "In the Pliocene, Benicia,

Solano County, and San Diego, California." — Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 213, 1952. Cosmopolitan. — Soot-Ryen, Alan Hancock Pac. Exped., Vol. 20, No. 1, p. 19, pl. 1, figs. 1, 2, text figs. 1, 2, 10, 11, 1955. Cosmopolitan.

Type locality. — "Habitat in O Europaeo, Indico & M. Balthico."

Remarks. — The only record of the occurrence of *Mytilus edulis* in the Pliocene at San Diego is that of I. S. Oldroyd. We have not observed any specimens in the collections from the San Diego Formation which are referable to this species and we are therefore unable to validate the record of Oldroyd.

This species has been recorded from several other localities in California in strata of Pliocene age including the Falor Formation, Merced Formation, San Joaquin Formation (cf.), and in the Fourth Street Tunnel in Los Angeles. It also has been recorded as occurring from middle Miocene (139) to Recent in this region.

Mytilus edulis, or subspecies of it, occur in most of the seas of the world except in extreme tropical waters. Field (140) gave an extensive discussion of its biology and economic value and Seed (141) recently discussed the variation in the shape of the shell of this species.

SUBGENUS *CRENOMYTILUS* SOOT-RYEN

Crenomytilus Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 23 November 10, 1955. "Type of genus: *Mytilus grayanus* Dunker, 1853."

Mytiloconcha of west American authors, not *Mytiloconcha* Conrad, 1862.

Type species (by original designation). — *Mytilus grayanus* Dunker [Zeitschr. f. Malakozool., Jahrg. 10, No. 6, p. 84, July, 1853. "Habitat ad insulam Javam." Illustrated by Soot-Ryen, 1955, p. 24, pl. 2, figs. 9, 10, text fig. 7. Japan. — Habe and Ito, Shells of the world in colour, Vol. 1, The northern Pacific (Hoikusha: Osaka, Japan), p. 112, pl. 36, fig. 5, 1965].

Range. — Late Oligocene or early Miocene to Recent.

Original description. — Shell mytiliform with terminal umbones, lunule grooved and incurved, forming two to three large teeth usually obsolete in old specimens, as there is a pronounced tendency to a growth in thickness by depositing new shell material on the inside of the valves. Margins, especially the anteroventral one, finely crenulated, the crenulations apparently formed as a result of the building up of the crystals in the valves; shell obliquely striated, especially distinct on the ventral surface. Resilial ridge compact; anterior adductor strong, showing a distinct thickened scar; anterior retractor scar elongate behind umbo; posterior adductor and retractor scars continuous. The soft parts have not been studied. (Soot-Ryen, 1955.)

This group of mytiliform species is distinguished from similar forms by the compact resilial ridge, the strong anterior adductor and the fine crenulation of the margins. (Soot-Ryen.)

Remarks. — West American Tertiary species referred to *Crenomytilus* by Soot-Ryen are: *Mytilus mathewsonii* Gabb, *M. trampasensis* Clark, *M. kewi* Nomland, and *M. coalingensis* Arnold. The new subspecies, *M. coalingensis sternbergi*, obviously belongs with this group of species. *Mytilus schencki* Hanna and Hertlein, described from strata of late Miocene age, is probably referable to the subgenus *Crenomytilus* but we have not seen specimens in which uneroded margins could be observed. The only Recent species referred to this subgenus by Soot-Ryen was the type species, *M. grayanus* Dunker (*M. dunkeri Reeve)*, from Japan and neighboring regions.

Mytilus (Crenomytilus) coalingensis sternbergi
n. subsp.
Plate 41, Figures 10, 14

Mytilus coalingensis Arnold, Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 85, 1929. "San Diego fauna". "Pliocene." — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. "San Diego formation." Also Niguel Formation and Careaga Sandstone and upper part of Foxen Mudstone.

Not *Mytilus (Mytiloconcha) coalingensis* Arnold, U. S. G. S., Bull. 396, p. 73, pl. 19, fig. 5; pl. 22, fig. 6, 1909 [issued January 10, 1910]. Type locality 4656, (see p. 33), "at northwest end of Anticline Ridge, 6 miles north-northeast of Coalinga, SW. 1/4 sec. 34, T. 19 S., R. 15 E." [Mount Diablo Base and Meridian]. "Lowest Etchegoin bed or *Glycymeris* zone, just below bed of 4657." "Etchegoin (upper Miocene)." [Pliocene.]

Mytilus sp. (large), Hertlein and Allison, Bull. South. Calif. Acad. Sci., Vol. 58, Pt. 1, January-April, p. 21, issued May 11, 1959. Three localities between kilometer marker 258, Ensenada-San Quintin highway, to terrace east of San Simon and Agua Chiquita, northwestern Lower California, late Pliocene.

Type specimen. — Holotype, Los Angeles County Museum, from Loc. 107 (LAM), 100-foot bluff with fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; San Diego Formation, middle Pliocene.

Additional Occurrences in San Diego Fm. — C.A.S. 1402. L.A.M. 302. S.D. 3209.

Description. — Shell large, resembling *Mytilus coalingensis* in general shape and trace of the lines of growth. It differs from that species in that the valves are less convex. Dimensions: length, 238 mm, width, 134 mm, convexity near the unbonal area, 59 mm.

Remarks. — The presence of a large anterior adductor impression on some of the present specimens is similar to that on the type species of *Crenomytilus.* Minute crenulations on the anterior ventral margin, characteristic of *Crenomytilus* are not visible on our specimens. Fine transverse rows of pustules on the exterior of the anterior ventral end of *M. coalingensis* from Pliocene strata in the San Joaquin Valley suggest that the inner margin of the valves of that species is crenulated.

One specimen, referred to the new subspecies in the collections of the California Academy of Sciences and one in the Los Angeles County Museum, consist of the beak and a portion of the umbonal area. A specimen in the latter institution from Loc. 302 (LAM) is 48.5 mm long and 33.6 mm in maximum width. A large anterior muscle impression similar to that of *M. coalingensis* is observable on these specimens.

One internal cast ("Steinkern") from Kensington Park in San Diego in the collections of the San Diego Society of Natural History is 130 mm long and 73 mm wide.

Woodring (142) mentioned the occurrence of casts

of a *Mytilus* in the Careaga beds and Foxen mudstone of Pliocene age in the Santa Maria district, which he compared with *M. coalingensis* but which he stated were flatter than the valves of that species. His description of these casts is reminiscent of the specimen from Loc. 3209 (SD).

The shell of *Mytilus coalingensis sternbergi* is broader posteriorly and it is more curved toward the beaks than is that of *M. mathewsonii* Gabb (143). The anterior ventral margin of the new subspecies is more curved than that of *M. mathewsonii expansus* Arnold (144) and *Mytilus kewi* Nomland (145). *Mytilus schencki* Hanna and Hertlein (146) is very much more broadly expanded posteriorly.

The new subspecies, at the present time, is known only from strata of middle Pliocene age in southern California and northwestern Lower California. *Mytilus coalingensis* is often encountered in beds of late Pliocene age in San Joaquin Valley. It has been recorded from as far north as the Sargent Oil Field (147) in Santa Clara Co., and specimens referred doubtfully to Arnold's species have been reported (148) from the lower Merced Formation in San Mateo Co., California.

Specimens cited as "*Mytilus coalingensis* Arnold, n. var.?" were reported by B. L. Clark (149) from beds presumably of late Miocene age in Contra Costa Co., California.

GENUS *AEIDIMYTILUS* Olsson

Aeidimytilus Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 120, March 10, 1961.

Type species (by original designation). — "Type species *Mytilus adamsiana* Dunker."

Range. — Middle Pliocene (and perhaps earlier) to Recent. Recent in Temperate and tropical waters, chiefly intertidal, reported to a depth of 55 to 91 meters (30 to 50 fathoms).

Original description. — Shell small, mytiliform with ribbed sculpture, usually divided, the ribs on the posterior-dorsal side of the umbonal ridge much coarser. Ventral side usually strongly impressed resulting in a high, angular umbonal ridge and often a distorted appearance to the whole shell. Adductor and pallial impressions united, but smaller and narrower than in *Scolimytilus*. (Olsson.)

Remarks. — Some of the west American Mytilidae with small shells, especially those described as *Mytilus multiformis* Carpenter and *Mytilus adamsianus* Dunker, have been variously placed in the generic or subgeneric categories of *Brachidontes* Swainson (150) and *Hormomya* Morch (151). Recently Olsson, believing that these small species combine some of the characters of both of the foregoing categories, proposed a genus *Scolimytilus* (152) and subgenus *Aeidimytilus* to include this group of species. We assign generic status to *Aeidimytilus* with the type species *Mytilus adamsianus* Dunker, at least until there is more general agreement concerning the systematics of these small mytilids.

The shells of this group usually develop a strongly arched umbonal ridge, coarse sculpture on the dorsal area and fine sculpture on the ventral area.

Aeidimytilus adamsianus Dunker
Plate 42, Figures 4, 5

Mytilus adamsianus Dunker, Proc. Zool. Soc. London for 1856, p. 360, issued May 8, 1857. — Reeve, Conch. Icon., Vol. 10, *Mytilus*, sp. 55, pl. 11, fig. 55, 1858. Panama. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 66, pl. 29, fig. 4, 1924. Santa Barbara, California, to Panama and the Galápagos Islands.

Mytilus stearnsi Pilsbry and Raymond, Nautilus, Vol. 12, No. 6, p. 70, "plate 4, figs. 1, 2, 3," October, 1898. "San Diego," California. [So far as we know the plate here referred to was not published.] — Gardner, Jour. Entom. Zool., Vol. 9, No. 3, p. 107, pl. 1, fig. 3, 1917. Laguna Beach, California. — M. Smith, Panamic Marine Shells (Trop. Photogr. Labor.: Winter Park, Florida), p. 53, fig. 694, 1944. San Diego, California, to Chile.

Mytilus (Hormomya) adamsianus Dunker, J. Q. Burch, Min. Conch. Club South. Calif., No. 36, p. 10, June, 1944. Cape San Lucas, Lower California, to Panama.

Mytilus (Hormomya) stearnsi Pilsbry and Raymond, T. Burch, Min. Conch. Club South. Calif., No. 36, p. 16a, fig., June, 1944. Punta Banda, Lower California, Mexico.

Brachidontes (Hormomya) adamsianus Dunker, Hertlein and Strong, Zoologica, Vol. 31, Pt. 2, p. 70, 1946. Santa Barbara, California to Panama, and the Galápagos Islands.

Hormomya adamsiana Dunker, Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 37, pl. 3, fig. 11; text-figs. 22, 25, 31, 1955. Santa Barbara, California, to Ecuador. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, Calif.), p. 48, fig. 83, 1958. California to the Gulf of California and south to the Galápagos Islands.

Scolimytilus (Aeidimytilus) adamsianus Dunker, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 121, pl. 12, fig. 5; pl. 13, figs. 4, 4a, 6, 1961. Lower California to Puerto Callo (Jipijapa), Ecuador.

Type specimen. — Type lot in British Museum (Natural History) (according to A. M. Keen, written communication, April 22, 1965).

Type Locality. — "Hab. Ad Isthmum Panamense (Cuming)."

Range. — Middle Pliocene to Recent. Recent from Santa Barbara, California, to Puerto Callo (Jipijapa), Ecuador, and the Galápagos Islands. Intertidal, usually under rocks and stones. Reported to a depth of 55 to 91 meters (30 to 50 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305C.

Original description. — M. testa ovato-trigona, utrinque obtuse carinata, solidula, costis mature bifidis eleganter granosis sculpta, fusco-purpurascente et albida; epidermide cornea vestita; umbonibus terminalibus; margine crenato.

Testa parva 10 lin. longa, 5 1/2 lin. alta, 4 1/2 lin. lata. (Dunker.)

Remarks. — Three valves of this species, somewhat eroded, are present in the collection from Loc. 305c (LAM), from near the Mexican boundary. The largest one is 18.9 mm long and 7.2 mm high (incomplete).

Other workers have remarked upon the variability in size and shape of a series of specimens of this species. This is probably, in part, a result of the habitat under stones and in crevices in rocks.

The beaks are small and nearly terminal and the umbonal ridge is high. The ribbing and general shell characters of the present valves agree exactly with specimens from west Mexico and Central America. The ribs on typical specimens of *Aeidimytilus adamsianus* are coarse on the dorsal area, they increase posteriorly by divarication or by addition. They are granulated as a result of successive step-like resting stages. The ribs on the ventral area are much finer. The dorsal area is brownish purple, the ventral area yellowish white. Interiorly the dorsal margin above the ligamental groove is strongly crenulated. The external appearance of this shell is remarkably similar to that of *Septifer bifurcatus*. Some specimens are sculptured with fine ribs but such forms agree in all other shell characters with the coarsely ribbed ones.

It appears that this species reaches a greater size in the northern part of its range. The largest specimens in the collections of the California Academy of Sciences, from three widely separated localities respectively are: from San Diego, 22.5 mm long and 12.3 mm high; from San Luis Gonzaga Bay, east coast of Lower California, 20.5 mm long; from Piedra Blanca, Costa Rica, 15 mm long. We are uncertain of the identification of the species from Costa Rica cited by Miller (153) under the name of *Mytilus adamsianus* which was 53 mm long and 34 mm wide.

We have not found any constant differences, other than size, in shells from southern California and those from Central America and the Galápagos Islands. This leads us to include *Mytilus stearnsi* Pilsbry and Raymond in the synonymy of *A. adamsianus* Olsson (1961) published excellent illustrations of this species.

Some authors have believed that the nomenclature of this species is involved with that of *Mytilus multiformis* Carpenter. An illustration of a drawing of *M. multiformis* by Carpenter, in the United States National Museum was published by Olsson (1961, pl. 17, fig. 11). According to Olsson, Carpenter's manuscript sketches indicate "a small, short, fan-shaped shell with a large, smooth, nepionic area followed by two or more sculptured areas set off sharply from each other and the nepionic disk by resting lines; . ." The shell characters of the species mentioned by Olsson are distinct from those of typical *A. adamsianus*. Another illustration of Carpenter's species was published recently by Brann (154.)

GENUS *SEPTIFER* RÉCLUZ

Septifer Récluz, Rev. Zool., Soc. Cuvierienne, Vol. 11, p. 275, 1848. — Davies, Tertiary Faunas (Thomas Murby and Co.: London), Vol. 1, p. 191, 1935. — Lamy, Jour. de Conchyl., Vol. 80, No. 3, p. 239, 1936. — Iredale, Brit. Mus. (Nat. Hist.), Great Barrier Reef. Exped., 1928-29, Sci. Repts., Vol. 5, No. 6, Moll., Pt. 1, p. 424, 1939. Type as designated by Stoliczka.

Type species (designated by Stoliczka, Mem. Geol. Surv. India, Palaeont. Indica, Ser. 6, Cret. Fauna South India, Vol. 3, pp. xxi, 366, 1871). — "type, *S. bilocularis*, Linn." [= *Mytilus bilocularis* Linnaeus, Syst. Nat., ed. 10, p. 705, 1758. "Habitat in O. Indico." For synonymy and a discussion see *Brachidontes (Septifer) bilocularis* Linnaeus, Prashad, Siboga Exped., Monogr. 53, p. 69, p. 2, figs. 21-24, 1932. East Indies. Widespread in the Indopacific.]

Range. — Triassic (155) to Recent. Recent from the intertidal zone to about 55 meters (30 fathoms).

Description. — Shell generally short, modioliform, with a high umbonal angle, the external surface sculptured with small radial riblets, often with bristles. Hinge and posterior margins strongly crenulated, the short anterior side with small dysodont teeth as in *Brachidontes* and with a small deck or platform placed like a shelf in the umbonal cavity below the beaks. (Olsson, A. A., Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 122, 1961.)

Remarks. — The presence of an umbonal deck interiorly readily serves to separate the shells of *Septifer* from other members of the Mytilidae.

Five species of this genus have been reported from strata of Tertiary age in California. One species is reported here for the first time from the San Diego formation. Two, possibly three species, live in eastern Pacific waters.

Lamy (1936) discussed Recent species of this genus represented in the collections of the Museum of Natural History in Paris.

Septifer bifurcatus Conrad
Plate 42, Figures 6, 12

M[ytilus]. bifurcatus Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 241, pl. 18, fig. 14, 1837. — Reeve, Conch. Icon., Vol. 10, *Mytilus*, sp. 41, pl. 9, fig. 41, 1857.

Septifer bifurcatus Conrad, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 119, 1903. Pleistocene and Recent. — Gardner, Jour. Entomol. Zool., Vol. 9, No. 3, p. 107, pl. 1, fig. 4, 1917. Laguna Beach, California, Recent. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 247, 1931. Pleistocene and Recent. — Johnson and Snook, Seashore Animals of the Pacific Coast (Macmillan Co.: New York), ed. 1935, p. 429, fig. 389 (p. 430), 1935. "Northern California to the Gulf of California." — Nomura, Venus, Vol. 6, No. 4 p. 206 (in text), figs. 6a-d, 1936. California. — Ricketts and Calvin, Between Pacific Tides (Stanford Univ. Press: Stanford, Calif.), p. 99, pl. 22, fig. 3, 1939. Recent. — Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 41, pl. 4, figs, 19, 20; text fig. 33, 1955. Crescent City, California, to Cabo San Lucas, Baja California, Recent.

Type specimen. — No. 57920, Academy of Natural Sciences of Philadelphia (see A. M. Keen, Veliger, Vol. 8, No. 3, p. 169, 1966).

Type locality. — "Inhabits, attached to rocks bare at low water, in the Sandwich Islands, (Ouau, &)." [Locality erroneous. This species is now believed to be a member of the molluscan fauna of California. See note by Henderson (Nautilus, Vol. 40, No. 3, p. 81, 1927) dealing with Californian species erroneously described from Hawaii by Conrad; also Keen, A. M., Min. Conch. Club South. Calif., No. 36, p. 11, June, 1944.]

Range. — Middle Pliocene to Recent. Recent from Crescent City, California, to Asuncion Island, and perhaps to Cape San Lucas, Lower California, Mexico. Often attached by byssus to underside of rocks; to 22 meters (12 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305C. S.D.S.C. 47.

Original description. — Shell narrowed, slightly arcuate; anterior margin much flattened; ribs narrow, prominent, bifurcated towards the base; colour dark purple. Height, one and a half inches. (Conrad.)

Remarks. — *Septifer bifurcatus* is here reported for the first time from strata of Pliocene age. One valve, somewhat eroded, 18.2 mm long and 10.8 mm wide, is present in the collection from Loc. 47 (San Diego State Coll. Dept. Geol. Coll.) from Tijuana River Valley. One valve, 10 mm long from near the Mexican boundary, is present in the collections of the Los Angeles County Museum. The largest Recent specimen in the collections of the California Academy of Sciences collected by Henry Hemphill at Loc. 5889 (CAS), San Diego, California, is 41.5 mm long and 18 mm high. Some large valves become partially or almost entirely smooth after attaining a length of about 25 mm. Shells similar to these with obsolete radial sculpture were described as *Septifer bifurcatus* var. *obsoletus* Dall. (156)

The species living in tropical and subtropical west American waters formerly referred to *Septifer cumingii* Récluz is now known as *S. zeteki* Hertlein and Strong (157).

Records by Melvill and Standen (158) of *S. bifurcatus* from the vicinity of the Falkland Islands are undoubtedly referable to some other species.

A species in Japan, formerly cited under the name of *Septifer bifurcatus* Conrad, later described as *S. keeni* by Nomura (159), is now referred to *S. grayanus* Dunker (160) by Habe (161).

Septifer margaritana Nomland (162), a species of late Miocene age from about ten miles northeast of Coalinga, California, was described as larger (52 mm long, 22 mm high) than *S. bifurcatus*, with more numerous radiating riblets and with a more acute umbonal angulation. We have examined a cast of the holotype which reveals the shell characters mentioned by Nonland.

GENUS *MODIOLUS* LAMARCK

Volsella Scopoli, Introd. Hist. Nat., p. 397, 1777. Species cited, "*Mytilus Modiolus* Linn. dente unico"; "*Gula Soricis* Lister. dentibus 1-2)."; "*Mytilus. L.* Aber. Adans. dentibus pluribus." [According to E. Fischer-Piette et al. (Jour. de Conchyl., Vol. 85, No. 4, p. 298, pl. 13, fig. 2, 1942) *Gula soricis* Lister is referable to *Brachidontes puniceus* Gmelin.] — Gray, Proc. Zool. Soc. London for 1847, p. 198, 1847. Type, *Mytilus modiolus* Linnaeus. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 248, 1931. Type as indicated by Gray.

Modiolus Lamarck, Mem. Soc. Hist. Nat. Paris, p. 87, 1799. Sole species, "*Mytilus modiolus.*" — Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20 No. 1, p. 56, 1955. Type (according to Gray, 1847): *Mytilus modiolus* Linnaeus. [*Modiolus* ruled a *nomen conservadum* and placed on the official list of generic names in Zoology with the type species, *Mytilus modiolus* Linnaeus, by Internatl. Comm. Zool. Nomencl., Opinion 325, signed May 8, 1954, published January 7, 1955.]

Modiola Lamarck, Syst. Anim. S. Vert., p. 113, 1801. Sole species "*Modiola papuana*, n. Argenv. t. 22, fig. C. Encycl. t. 219, fig. 1. Chemn. 8, t. 85, f. 757. Vulg. la moule des Papous." — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 4, p. 150, April, 1890. — Jukes-Brown, Proc. Malacol. Soc. London, Vol. 6, No. 4, p. 221, March, 1905.

Eumodiola von Ihering, Proc. Malacol. Soc. London, Vol. 4, p. 87, August, 1900. "Type, *M. modiolus*, Linn."

Type species (by monotypy and by absolute tautonomy, and by ruling of the Internatl. Comm. Zool. Nomencl., Opinion 325) — *Mytilus modiolus* Linnaeus [Syst. Nat., ed. 10, p. 706, 1758. "*Habitat in* M. Mediterraneo." Ref. to Rumphius, Mus., t. 46, fig. B; Argenville, Conch., t. 25, fig. C.; Bradl. Nat., t. 3, fig. 1. Illustrated by Reeve, Conch. Icon., Vol. 10, *Modiola*, pl. 1, fig. 2, 1858. "North Atlantic shores of Europe and America." — Clessin in Martini and Chemnitz, Conchyl. Cab., Bd. 8, Abt. 3, Mytilidae, p. 92, pl. 5, fig. 3, 1889. — Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 66, text figs. 47, 48, 52, 1955].

Range. — Devonian to Recent, world wide, marine. Recent from the intertidal zone to a depth of at least 183 meters (100 fathoms).

Description. Shell obliquely oblong, expanded posteriorly and inflated along an oblique medial line from the unbonal end to the posterior ventral margin; dorsal margin curved or angulated; anterior end usually produced beyond the umbones; exterior with a hairy periostracum; hinge edentulous or often with a tooth-like projection on anterior margin just below the anterior end of the ligament.

Remarks. — A number of species of *Modiolus* have been described from strata of Tertiary age in western North America of which five have been recorded as occurring in beds of Pliocene age. Eight Recent species living in west American waters were assigned to this genus by Soot-Ryen. These range from the intertidal zone to a depth of 183 meters (100 fathoms) but most of them occur most abundantly in waters less than 92 meters (50 fathoms) in depth. Many of the species build "nests" of sand and byssus threads.

Modiolus rectus Conrad
Plate 42, Figure 7

M [odiola]. recta Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 243, pl. 19, fig. 1, 1837. — Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, December, 1874. Also printed in advance, March 26, 1874. "Well at San Diego," Pliocene. — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. Well at San Diego. — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. California State Mineral. for 1888, p. 251, 1888. "San Diego well." Also other localities. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Orcutt's citation of Dall's (1874) record.

Not *Modiola recta* Collignon, Ann. Géol. Serv. Mines de Madagascar, Vol. 16, p. 16, pl. 2, figs. 5, 6, 1949. Albian, Cretaceous, Madagascar.

Modiolus rectus Conrad, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 120, 1903. "San Diego well (Cooper): San Diego (Arnold)." "Pliocene." — Arnold, U. S. G. S., Prof. Paper 47, p. 28, 1906. "San Diego formation" at Pacific Beach, Pliocene. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 181, 1912. "San Diego-Purisima". — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 151, 1919. "San Diego", Pliocene. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1., p. 68, 1924. "San Diego well; San Diego well; San Diego". — Waterfall, Univ. Calif. Publ., Bull. Dept. Geol. Sci., Vol. 18, No. 3, opp. p. 78, 1929. "San Diego Pliocene."

Volsella recta Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 250, 1931. Cooper's record (1888), and Arnold's records (1903), cited.

Type specimen. — Location of type specimen unknown to the present authors.

Type locality. — "Inhabits sandy shores near Sta. Barbara; rare."

Range. — Late Miocene to Recent. Recent from Vancouver Island, British Columbia, to Concepcion Bay, east coast of Lower California; intertidal zone to about 46 meters (25 fathoms).

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 957, 1178, 1186, 1400, 28880, 28886, 28889, 31320. L.A.M. 103, 305, 305A. S.D. 25, 29, 408. U.C.L.A. 302.

Original description. — Shell produced, smooth, thin; anterior margin elevated; posterior side cuneiform; colour brown, with a broad pale stripe extending from the beak towards the posterior margin; within very glossy and irridescent. Length, two inches. (Conrad.)

Remarks. — Most of the specimens representing this species in collections from the San Diego Formation are imperfectly preserved. The largest specimen, a right valve from Loc. 305A (LAM), is 94 mm long and 42 mm high. The extreme anterior end is lacking but the remainder of the shell is comparable to Recent specimens of *Modiolus rectus* which lives in adjacent waters at the present time. A specimen collected by R. E. Lando, from Loc. 31320 (CAS), 68.8 mm long, also lacks the anterior portion of the shell.

Modiolus flabellatus Gould (163), considered by some authors to be a more alate form of *M. rectus* was placed in the synonymy of the latter species by Soot-Ryen.

Modiolus directus Dall (164), described from the Empire Formation of Pliocene age in Oregon, was said to differ from *M. rectus* in that "the anterior end of *M. directus* is proportionally much shorter than in *rectus*, and the posterior end still more so; the fossil is not alate above like the variety *flabellatus* Gould, and it is also more arcuate than *rectus*." Considerable variation exists in a series of specimens of *M. rectus*, Recent as well as fossil. Authors vary in their opinions concerning the taxonomic status of *M. directus*. Arnold and Hannibal (165), Howe (166) (questionably), and Grant and Gale, all placed it in the synonymy of *M. rectus*; but Etherington (167), Weaver (168), and more recently Moore, (169) treated it as a distinct species of Miocene age.

Modiolus rectus occurs rather commonly at various localities in California in beds of Pliocene age. At the present time this mollusk lives on a muddy bottom with the anterior portion embedded in a nest in the mud but with the posterior portion of the shell exposed above the surface of the bottom. Specimens are often found which are 120 mm to 130 mm in length but huge forms are reported to attain a length of 230 mm.

Modiolus sacculifer Berry
Plate 41, Figures 2-4

Vosella sacculifer S. S. Berry, Trans. San Diego Soc. Nat. Hist., Vol. 11, No. 16, p. 407, pl. 28, figs. 1, 2, text fig. 1, September 1, 1953.

Modiolus sacculifer Berry, Soot-Ryen, Allen Hancock Pac. Exped., Vol. 20, No. 1, p. 65, text-figs. 57a-b, 58, November 10, 1958. Type locality cited. Range, "Bechers Bay, California, south to San Clemente Island, California." Recent.

Type specimen. — No. 7853, Stanford University, Department of Geology.

Type locality. — "San Pedro harbor, California."

Range. — Middle Pliocene to Recent. Recent from Monterey to Long Beach, also Bechers Bay, Santa Rosa Island, and San Clemente Island, California, from low tidal zone to 102 meters (56 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A.

Original description. — Shell of but moderate size for the genus, in outline broadly almond-shaped; highest at about the mid-point, thin, smooth, moderately inflated; hinge-line nearly straight to very slightly arcuate. Valves well rounded behind, more or less distinctly swollen ventrally in the byssal region and produced abruptly into a small obtuse lobe-like flare or pocket just under the umbones, the rounded angle of this pocket forming the anterior end of the shell; postero-dorsal area subalate, its angle obtuse. Hinge toothless except for a short, sharply conical, posteriorly directed process set off by a notch at the anterior insertion of the ligament. Periostracum light to deep brown (near Buckthorn Brown to Mummy Brown), smooth, polished, under the more or less dehiscent traces of some fairly considerable posterior shagginess. (Berry.)

Measurements. — holotype, maximum length, 38.0 mm, maximum altitude, 20.0 mm, diameter, 15.8 mm. (Berry.)

Remarks. — Several single valves, the largest 52.2 mm long, in the collections of the Los Angeles County Museum are identical with Recent specimens of *Modiolus sacculifer*. Many fragments consisting of the anterior ends of valves also are probably referable to this species.

A large Recent specimen of this species from San Pedro, California, is 57.5 mm long (beak to base), height 34 mm, convexity (both valves together), 26.4 mm.

The shell of *M. sacculifer* is readily separable from that of *Modiolus carpenteri* Soot-Ryen (170), a new name for *Modiola fornicata* Carpenter (171), in that the lobe-like anterior end extends beyond the beaks whereas in Soot-Ryen's species it does not.

Modiolus inflatus Dall (172), described from beds of Pliocene age at Coos Bay, Oregon, was later named *M. trinominatus* by Hanna (173). Dall compared his species with *M. fornicatus* [= *M. carpenteri*]. Recent specimens of *M. sacculifer* agree with Dall's illustration of *M. inflatus* except that the anterior end of the fossil is broader and the lobe-like character of the anterior extremity is not clearly observable. Dall mentioned that the

anterior end of *M. inflatus* is narrow and rounded.

Through the courtesy of Dr. G. A. Cooper, United States National Museum, we have had the opportunity to examine the type specimens of that species. It appears obvious that the preservation of the holotype is not perfect. The general outline of a virtual paratype accompanying the holotype agrees well with *M. sacculifer* but the anterior end of this specimen also is imperfect. If perfect specimens of the Oregon fossils are found showing a lobe-like, pouting anterior end, it is not unlikely that the earliest name available for the Recent species named *M. sacculifer* may be *M. trinominatus.*

GENUS *GREGARIELLA* MONTEROSATO

Gregariella Monterosato, Nomenclatura Generica e Specifica di alcune Conchiglie Mediterranee, p. 11, 1884. Species Cited: "*G. sulcata*, Risso *(Modiolus sulcatus)* — 1826, p. 324 (Alpi Marit.)" with synonyms, and "*G. gibberula*, Caillaud *(Modiola)* — Catal. ecc. Nantes 1865, p. 109, t. 4, 9-12 (Loire Inférieure)" with synonyms. — Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 76, 1955. Type of genus: *Modiolus sulcatus* Risso 1826 (*non* Lamarck 1805, 1819). — Olsson, Mollusks of the Tropical eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 128, 1961. Type species as designated by Crosse.

Botulina Dall, U. S. Nat. Mus., Bull. 37, p. 38, 1889. Sole species, "*M. opifex* Say." "Hatteras."

Trichomusculus Iredale, Proc. Linn. Soc. New South Wales, Vol. 49, Pt. 3, p. 196, October 24, 1924. "I propose the new genus *Trichomusculus*, with *barbatus* as type." P. 181, "for *Lithodomus barbatus* Reeve."

Tibialectus Iredale, Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29, Sci. Repts., Vol. 5, No. 6, Moll., Pt. 1, p. 424, February 25, 1939. "Type: *T. otteri*, sp. nov.", p. 424, pl. 6, fig. 24.

Type species (designated by Cross, Jour. de Conchyl., Vol. 33 (Ser. 3, Vol. 25), No. 2, p. 140, 1885). — "type: *Modiolus sulcatus*, Risso)." [*Modiolus sulcatus* Risso, Hist. Nat. Europe Mérid., Vol. 4, p. 324, 1826 (not *Modiolus sulcatus* Lamarck, 1805). "Sej. Régions profundes. App. Printemps." Illustrated by Clessin, Conchyl. — Cab. von Martini und Chemnitz, ed. 2, Bd. 8, No. 3, p. 138, pl. 36, fig. 5 (as *Modiola sulcata*). — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 4 (Pelecypoda, Fasc. 17), p. 170, pl. 29, figs. 29, 30, 31, 32, 1890 (as *Modiolaria sulcata*). See also Reeve, Conch. Icon., Vol. 10, *Modiola*, sp. 46, pl. 8, fig. 46, 1857 (as *Modiola petagnae* Scacchi).]

Range. — Miocene to Recent. Recent in from 4 to 91 meters (2 to 50 fathoms).

Description. — Shell modioliform, valves convex often angulated from the umbo to the posterior margin, beaks nearly terminal, hinge line short, posterior end attenuated; sculpture similar to that of *Musculus*, radial riblets divaricating along the medial umbonal slope, but an anterior median ventral area smooth, decussated sculpture sometimes formed when the radial riblets are crossed by thickened concentric lines of growth; posterior area covered with a brown periostracum bearing hair-like filaments and these may continue anteriorly along the central angulation; inner margin finely crenulated corresponding to the ends of the radial riblets; resilifer narrow, often with dysodont teeth; anterior adductor large, oval. Usually burrowing forms. (Adapted chiefly from Olsson, 1961.)

Remarks. — This is the first record of *Gregariella* from the Pliocene of California. Three species now live in west American waters. Others live in the Caribbean, Mediterranean, and Indo-Pacific regions.

Gregariella chenui Récluz
Plate 41, Figures 1, 5; Plate 42, Figures 1, 8

Mytilus (modiola) chenui Récluz, Rev. Zool., Soc. Cuvierienne, Vol. 5, p. 306, 1842.

Mytilus chenuanus d'orbigny, Voy. Amér. Mérid., Vol. 5, Moll., p. 649, pl. 85, figs. 14-16, 1846. "Elle a été recueillie au Brésil par M. Fontaine; elle se tient entre les rochers." [On explanation to plates, figs. 14-16 on plate 85 are referred to as *Mytilus fontaineanus.*]

Mytilus fontaineanus d'Orbigny, Voy. Amér. Mérid., Vol. 5, Moll., p. 710, pl. 85, figs. 14-16, 1846.

Mod. *(Gregariella) chenui* Récluz, Lamy, Jour. de Conchyl., Vol. 81, No. 1, p. 40, 1937. "Bahia."

Gregariella chenui Récluz, Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 78, pl. 8, fig. 40; text-fig. 65, 1955. Monterey, California, south to Bahia de la Independencia, Peru.

Modiola opifex of west American authors, not of Say, 1825.

Type specimen. — Location unknown to the present authors.

Type locality. — "Hab. les côtes du Brésil, province de Bahia."

Range. — Middle Pliocene to Recent. Recent from Monterey Bay, California to Bahia de la Independencia, Peru. (Soot-Ryen.) Also Brasil and Caribbean region, in from 2 to 91 meters (4 to 50 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305C.

Original description. — Coquille transverse, ovale, renflée, mince, marquée d'un angle obtus des sommets au bord posteriéur et plane en dessus, arrondie, étroite et plus courte antérieurement qu'au côté posterieur, lequel est plus rétréci et presque anguleux. Sommets petits, saillants, obtusément arrondis, placés très-près du bord antérieur et décortiques; l'extérieur est sculpté de très petits sillons longitudinaux, partant des crochets et rayonnant vers la base des valves: les sillons sont finement striés en dedans et ont un aspect presque onduleux; les antérieurs sont arqués et obliquent fortement en avant; les postérieurs ont une direction antérieure plus droit dans leur cours. Ces sillons et ces stries sont effacés sur le tiers antérieur des valves ou à peine apparents, et à cette place règne une dépression qui part des crochets, où elle est peu sensible et se continue en augmentant graduellement d'intensité jusqu'à la base des valves, qu'elle rétrécit légèrement dans leur longeur. La couleur de cette coquille est roussâtre, peinte longitudinalement d'une large fascie marron sur la partie deprimee et lisse. Toute la portion postérieure est couverte de poils jaunâtres, comme agglutinés entre eux, et dont les postérieurs sont disposés en trois ou quatre filaments roides, velus et saillants d'un à deux millimètres. Intérieur nacré et légèrement irisé. Charnière formée d'une série de denticules ou crenélures qui, très-saillantes antérieurement, se continuent sur toute la région supérieure des

valves, et viennent finir sur le milieu du côté postérieur, en s'affaiblissant graduellement dans leur cours. — Larg. 16, diam. 10, convex. 10 mill. (Récluz.) [A description in the Latin language also is given by Récluz.]

Remarks. — One right valve here referred to *Gregariella chenui*, 4.6 mm long and 2.5 mm high, is present in the collections of the Los Angeles County Museum from near the Mexican boundary. This is the first record of this species in the San Diego Formation.

This valve agrees in all particulars with specimens dredged off Catalina Island, California, in 55-90 meters (30-50 fathoms). The radial sculpture on both the fossil and on the Recent shells is well developed and beaded posteriorly where crossed by coarse concentric lines of growth. The largest valve in the lot from off Catalina Island is 9.4 mm long and 4.6 mm high.

This species has been cited under the names of *Botulina* or *Gregariella opifex* Say and *B. denticulata* Dall. Soot-Ryen discussed the problems connected with the correct name for this species. He accepted *Gregariella chenui* as the earliest name applicable to both the east and west American species of *Gregariella*.

The species described as *Modiolus opifex* Say (174) originally came "Amongst a number of marine shells from the island of Minorca," on "a single valve of the *Pecten nodosus*, Linn.", "attached by a broad base to the surface of the Pecten." The dimensions were given as "Breadth nearly half an inch; length more than one-fifth of an inch." The illustrations depict a weakly sculptured shell similar in shape to a *Gregariella*.

There appears to be no reason to doubt the locality given for this species by Say. Until evidence can be presented which definitely places Say's species as living in east American waters, it seems best to follow Soot-Ryen's decision to recognize *Mytilus chenui* Récluz as the earliest name available applicable to the east American species of *Gregariella* formerly cited as *G. opifex*. We have not had specimens of *G. chenui* from Brazil available for comparison but we have no good reason to question Soot-Ryen's identification of west American forms with that species. The reported range, however, is very great, from Brazil to Monterey, California. Olsson (1961, p. 129) mentioned that he did not find it in the Panamic region. Confirmation of the identity of the Brazilian species with the one from California is desirable.

Gregariella denticulata Dall (175) has been confused with *G. chenui* but Keen (176) recently clarified this matter and illustrated the type specimen. She described it as a pearly white shell covered with a brown to black, bearded periostracum.

The sculpture on the shell of *G. chenui* is much coarser, the posterior end more rounded and the umbonal slope is less angulated than that of *G. coarctata* Dunker in Carpenter (177). Specimens of *G. coarctata* which we have seen are larger than those of *G. chenui*.

Odhner (178) reported a species under the name of "*Modiolaria (Gregariella) opifex* Philippi" from Mas Atierra, west of Chile, in 35 to 40 meters. The maximum length of the specimens was 10 mm. We have not seen specimens from that area.

GENUS *LITHOPHAGA* RÖDING IN BOLTEN

Lithophaga Röding in Bolten, Mus. Boltenianum, p. 156, 1798. Species cited, "*L. Mytuloides.* Der Muschelartige Steinbohrer. Gmel. *Mytilus lithophagus.* sp. 6. Chemn. 8. t. 82. f. 729. 730." — Iredale, Brit. Mus. (Nat. Hist.), Great Barrier Reef Exped. 1928-29, Sci. Repts., Vol. 5, No. 6, Moll., Pt. 1, p. 416, February 25, 1939. "Haplotype: *L. mytuloides* = *M. lithophagus* Gmelin." — Cox, Mem. Geol. Surv. India, Palaeont. Indica, Ser. 9, Vol. 3, Pt. 3, p. 73, 1940. "Genotype. — *Mytilus lithophagus* Linné (1758, p. 705)". — Gardner, Geol. Soc. Amer., Mem. 11, p. 57, 1945. "Type, by monotypy: *Mytilus lithophagus* Linnaeus = *Lithodomus dactylus* Sowerby." — Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 91, 1955. "Type of genus: *Lithophaga mytuloides* Röding 1798 = *Mytilus lithopagus* Linné 1780."

Lithophagus Megerle von Mühlfeld, Gesell. Naturfor. Freunde zu Berlin, Vol. 6, Abt. 1, p. 69, 1811. Species cited, "*Lithophagus communis.*"

Lithodomus Cuvier, Le Règne Anim., Vol. 2, p. 471, 1817 [December, 1816, according to Iredale, 1939]. Type designated by Sowerby (Gen. Rec. Foss. Shells, Vol. 2, No. 23, *Lithophaga*, 1824): "The type of this genus is the *Mytilus Lithophagus* of authors, which is very common in the Mediterranean, West Indies, and in all Coral rocks." Also by Herrmannsen, Indic. Malacozoor., Vol. 1, p. 611, 1847): "Typus: *Mytilus lithophagus* Linn."

Lithotornus Cuv., Schweigger, Handbuch Naturgesch, p. 712, 1820. Error for *Lithodomus* Cuvier, corrected on p. 776.

Type species (by virtual monotypy and by subsequent designation, Dall, Jour. Conch., Vol. 11, No. 10, p. 296, April, 1906). — *Mytilus lithophagus* Gmelin [= *Mytilus lithophagus* Linnaeus, Syst. Nat., ed. 10, p. 705, 1758. "Habitat in O. Indico, Europaeo, Mediterraneo, penetrans. & exedens Marmora, Corallia &." Ref. to "List. angl. 235. t. 8. f. 37", "Rumph. mus. t. 46. f. F. *Pholas*"; "Gault. test. t. 90. f. D.", and others. Illustrated by Chemnitz, Syst. Conch. -Cab., Vol. 8, 1785, p. 147, pl. 82, figs, 729, 730. Also by Reeve, Conch. Icon., Vol. 10, *Lithodomus*, species 9, pl. 2, fig. 9, 1857, and by Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Tome 2, p. 160, Fasc. 4 (Pelecypoda, Fasc. 17), p. 160, pl. 28, figs. 12-15, 1890. For a discussion of this species, see Dodge, H., Bull. Amer. Mus. Hat. Hist., Vol. 100, Art. 1, p. 208, 1952].

Range. — ? Late Paleozoic. Late Triassic (Frech) to Recent. Recent world-wide in warm temperate and especially in tropical and subtropical waters, from intertidal zone to 91 meters (50 fathoms), rarely deeper. *Lithophaga aristata* reported from a depth of 302 meters (165 fathoms) by Soot-Ryen (1955, p. 98).

Description. — Shell sub-cylindrical, strongly inflated, elongate, not very oblique; umbones obtusely rounded, placed near or at the anterior end. Anterior end evenly rounded and inflated, posterior end rounded or tapering. Valve margins closed, without a byssal gape. Dysodont teeth absent. Ligament elongate, narrow, subexternal, supported, as in *Modiolus* and *Mytilus*, by an internal ridge which continues the antero-dorsal margin. Anterior adductor rather ventrally placed, nearly as large as the posterior one. Surface either smooth, or with fine transverse striations, or with coarse transverse ridges confined to the posterior end, or with radial ribs at the post-

erior end; or, in some species, partly coated with a calcareous incrustation. Habitat rock-boring. (Cox, 1940.)

Remarks. — *Lithophaga* is represented by but few species in beds of Tertiary age in California. Two species have been described from the Eocene, one unidentified form in the early Miocene and one species in the Pliocene. Fragments and imperfectly preserved specimens are here reported for the first time from the San Diego Formation. Nine species and subspecies, arranged in six subgenera, are recognized by Soot-Ryen as occurring in waters between southern California and Chile. Only one reaches Californian waters.

This genus is believed to be derived from *Modiolus.* The various species bore into rocks as well as into corals and thick molluscan shells. They accomplish this process by means of a specially secreted acid. This boring process has been discussed by Kühnelt (179) and by Hodgkin (180). The boring activities of *Lithophaga* and other animals in coral reefs were described by Otter (181). Verrill (182) mentioned that the shells of nearly all mollusks that bore into rocks are luminous or phosphorescent.

Lithophaga sp.

Occurrence in San Diego Fm. — L.A.M. 107, P.87.

Remarks. — Two casts from India and Upas streets, San Diego, the larger one 24.6 mm long, are present in the collections of the Los Angeles County Museum. Unornamented fragments of the interior layers of the shell also are present. The general shape of the casts corresponds fairly well with Recent specimens of *Lithophaga plumula kelseyi* Hertlein and Strong (183), of comparable size, living in adjacent waters. This form was referred by Soot-Ryen (184) to *L. subula* Reeve (185), a species described without information concerning the locality from which it came. The imperfect preservation of the fossils makes positive identification of them with *L. p. kelseyi* a matter of uncertainty. Willett (186) reported what may be this form from beds of late Pliocene age at Fifth and Hope streets in Los Angeles.

Two fragments, casts retaining occasional patches of the internal portion of the shell material, are present from Loc. 107 (LAM). The larger one, an anterior portion of the specimen is 29.6 mm long and the maximum convexity (both valves together), is 18.6 mm. The size and general shape of the two fragments bear a resemblance to *Lithophaga attenuata* Deshayes (187) but because of the incomplete state and lack of shell material we hesitate to refer these casts to any named species.

Four casts and impressions of a *Lithophaga*, retaining some of the shell material, are present in the collections of the Los Angeles County Museum but without information as to the locality from which they came. The matrix is not unlike that from Loc. 107 (LAM). The largest impression of a valve is about 55 mm long and 15 mm high. The shape is similar to that of *L. attenuata* but the preservation is too imperfect to permit identification of the species with certainty.

Berry proposed the name *Lithophaga (Labis) attenuata rogersi* (188) for a form living in the Gulf of California.

GENUS *CRENELLA* BROWN

Crenella T. Brown, Illustr. Conch. Great. Brit. and Ireland (189), p. 1, pl. 31, figs. 12-14, 1827. Species cited, "*Crenella elliptica* Brown" in the synonymy of which was "*Mytilus decussatus*, Laskey in Wern. Mem. 1, p. 394, pl. 8, fig. 17. — Mont. Test. Brit. Sup. p. 69." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 801, 1898. "Type *Mytilus decussatus* Montagu, 1808." — Eames, Philos. Trans. Roy. Soc. London, Ser. B, Biol. Sci., No. 627, Vol. 235, p. 370, June 26, 1951. "Type species. *Crenella elliptica* (Leach MS.) Brown, Recent = *Mytilus decussatus* Montagu, in Macgillivray; monotypy, and Stoliczka, 1871." — Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 63, 1953. "Type by monotypy; *Mytilus decussatus* Montagu."

Type species (by subsequent designation, Stoliczka, Mem. Geol. Surv. India, Palaeont. Indica, Ser. 6, Vol. 3, p. XXI, 1871). — "Typical species. *Cr. decussata*, Montg." [= *Mytilus decussatus* Montagu, Test. Brit., Suppl., Vol. 3, p. 69, 1808. "in sand on the Scottish coast." Ref. to "Chem. Conch. VIII. t. 85. f. 761?" Also illustrated by Clessin, Martini-Chemnitz Conchyl. — Cab., ed. 2, Bd. 8, Abt. 3, Mytilacea, p. 149, pl. 34, figs., 13-14, 1889. — Tebble, British Bivalve Seashells [British Museum (Nat. Hist.)], p. 48, text fig. 19a, 1966.]

Range. — Late Cretaceous to Recent. Recent in from 2 to 4188 meters (2290 fathoms).

Description. — Shell small or medium sized, sometimes minute, obliquely-ovate, convex, with small, incurved, prosogyrate beaks. Prodissoconch usually well preserved, smooth. Interior often thickened, pearly, the outer surface covered by a thin, closely adhering epidermis. Hinge mytiloid, with small tooth-like knobs on the anterior margin bordered on the posterior side by a deep, furrow-like pit for the attachment of the ligament which is wholly internal. External sculpture composed of fine radials crossed or decussated by concentrics, often divaricated along the middle line of the umbonal slope. Inner margin crenulated by the ends of the external riblets all around, sometimes extending into the hinge itself, producing a pseudotaxodont pattern. (Olsson and Harbison.)

Remarks. — Some authors have placed in the synonymy of *Crenella* the genera *Stalagmium* Conrad, *Hippagus* Lea, and *Myoparo* Lea, but Eames presented reasons for excluding these from Brown's genus. *Nuculocardia* d'Orbigny however, is generally relegated to the synonymy of *Crenella.*

The shells of *Crenella* are small and it is often difficult to separate the species. Most of the Recent species of this genus live in cool waters but a few occur in tropical waters.

Gray, 1840, placed this genus in a family Crenellidae.

Some of the species of Cretaceous and Tertiary age described under the genus *Crenella* are referable to *Arcoperna* Conrad (190). According to van de Poel (191) a shell character of *Arcoperna* which may be relied upon to separate it from *Crenella* is the presence of a narrow, smooth band which extends from the beak to the anterior ventral margin.

The shells of species assigned to the genus *Arvella* Bartsch (192) resemble *Musculus* Röding in Bolten in outline and have much broader, coarser, radial ribs than those of *Crenella. Botulopsis* Reis (Geogn. Jahreshefte, Bd. 39, p. 124, 1926), described from strata of Triassic

age, is believed to be a member of the *Crenella* group.

Crenella inflata Carpenter
Plate 41, Figure 11

?Crenella inflata Carpenter, Ann. Mag. Nat. Hist., Ser. 3, Vol. 13, p. 313, April, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 211, 1872. — K.V.W. Palmer, Bull. Amer. Paleo., Vol. 46, No. 211, p. 302, 1963. Cape St. Lucas (Xantus). "The type of *C. inflata* has not been found nor has it been illustrated."

Not *Crenella inflata* Müller, Holzapfel, Palaeontographica, Bd. 35 (Moll. Aachener Kreide, Abt. 2), p. 220, pl. 25, figs. 17, 18, 1889. [This species was originally described as *Mytilus inflatus* Müller, Monogr. der Petrefacten der Aachener Kreideformation (Bonn), p. 35, pl. 2, figs. 9, 9a, 1847. "im Grünsand bei Vaels, als steinkern auch am Schindanger."]

Crenella divaricata d'Orbigny, Hertlein and Strong, Zoologica, Vol. 31, Pt. 2, p. 75, pl. 1, figs. 12, 13, 1946. "Guadalupe Island, Off Lower California, Mexico, and the Gulf of California to Ecuador." — Soot-Ryen, Allan Hancock Pac. Exped., Vol. 20, No. 1, p. 80, pl. 8, figs. 42, 44, 1955. Huntington Beach and San Miguel Island, California, to Callao, Peru. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 50, fig. 88, 1958. Southern California to the Gulf of California and south to Peru.

Not *Nuculocardia divaricata* d'Orbigny, 1842. [Referred to the genus *Crenella* by later authors.]

Type specimen. — A specimen "marked as Carpenter's type, bearing USNM Catalog Number 3998" is in the collection of the United States National Museum (J. Rosewater, written communication, November 4, 1964). Keen (written communication, October 20, 1964) mentioned that "One slide is at the B. M. labelled by Carpenter, from Cape San Lucas. The specimen is missing, apparently broken."

Type locality. — "Cape St. Lucas," Lower California, Mexico.

Range. — Middle Pliocene to Recent. Recent from Huntington Beach and San Miguel Island, California (Soot-Ryen) to the Gulf of California and south to Callao, Peru, in 4 to 91 meters (2 to 50 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A, 305C.

Original description. — ?C. testa valde inflata, minuta, albida, subrhomboideo-orbiculari; diagonaliter parum producta; marginibus subquadrangulatim rotundatis; umbonibus prominentibus, valde antice intortis; tota superficie ut in *C. decussata* sculpta, costulis crebris radiantibus aequidistantibus, hic et illic aliis intercalatis; lirulis concentricis decussantibus: intus margine dorsali brevissimo, arcuato, dentato; ligamento curtissimo, in fossa omnino interna, celata, lamina definiente, sito; lamina cardinali sub umbonibus intus porrecta, dentibus validis instructa; marginibus internis omnino crenatis; cicatr. adduct. subaequalibus, ventraliter sitis. Long. .1, lat. .12, alt. .09 poll. (Carpenter.)

Remarks. — Three specimens in the collections of the Los Angeles Museum, the largest 3 mm long and 2.3 mm wide, are here referred to the form described by Carpenter as "*?Crenella inflata.*" This identification is based upon identity with specimens identified by A. M. Strong as *C. inflata* from Cape San Lucas, the type locality of that form.

Some authors have considered *C. inflata* to be a synonym of *C. divaricata* d'Orbigny (193), originally described from Cuba, which they believed also lives in tropical west American waters.

We have not seen specimens from Cuba but we have based our conception of that species upon d'Orbigny's original description and figures, as well as upon those of other authors, which agree favorably with d'Orbigny's delineations.

Some Recent specimens from west American waters which have generally been considered to represent d'Orbigny's species, possess finer radial ribbing, less prominent concentric sculpture, and the umbos are less projecting and inflated than that of the fossil forms here referred to as *C. inflata.* Keen (1958, p. 50) considered *C. inflata* Carpenter and *C. ecuadoriana* Pilsbry and Olsson to be synonyms of *C. divaricata.*

Olsson (194), however, recently stated that "the Caribbean shell is thinner, less symmetrical in shape, usually with a larger, more conspicuous prodissoconch and with weaker sculpture." He assigned the tropical west American species referred to *C. divaricata* by Hertlein and Strong, to *C. ecuadoriana* Pilsbry and Olsson (195), a species described from strata of Pliocene age in Ecuador. Olsson recently described a subspecies, *C. ecuadoriana santiaga* (196) from strata of Miocene age in Ecuador. He also described *C. caudiva* (197), a Recent species from Ecuador, which he stated is "Distinguished easily from *C. ecuadoriana* by its unsymmetrical valves and subrhombic shape."

The fossils from the San Diego Formation bear a great similarity to some forms of *C. decussata.* Some authors have considered the west American *C. "divaricata"* to be a southern race of *C. decussata* as mentioned by Burch (198) who discussed the two species. The fossil specimens differ from typical *C. decussata* from England in the more elongately ovate shape, greater inflation, more projecting umbos and in the narrower interspaces between the radial ribs. The comparatively coarse ribbing on the fossil specimens resembles that of *C. decussata* more than it does the *"Crenella divaricata"* of west American authors. However, the relationship of the various west American species of *Crenella* is unknown and provisionally we leave Carpenter's *C. inflata* the rank of species.

ORDER ISODONTIDA DALL

SUPERFAMILY PECTINACEA RAFINESQUE (199)

Newell (200) gave a detailed discussion of the American Paleozoic groups of this superfamily.

FAMILY PECTINIDAE RAFINESQUE (201)

Shell usually of medium to large size, equivalve or inequivalve, orbicular to subtriangular, equilateral or nearly so; the valves may be alike in convexity and sculpture or they may be quite different, often slightly inflated or with one valve more inflated than the other, and may be thick or thin; monomyarian, with a single adductor muscle impression slightly posterior of the middle; beaks and umbones placed medially, usually with two triangular wings (auricles or ears), one on either side of the

umbo, the anterior one in the right valve usually with a distinct byssal sinus but this is almost lacking in some groups; surface smooth or with radial ribs or folds which corrugate the shell, sometimes with concentric lamellae; interior may be smooth or may bear radial riblets, hinge line straight, edentulous, taxodont in the very young but obsolete later, vertically striated in some groups; ligament in a central, triangular pit below the beaks, often with one or more oblique ridges of varying size diverging from it on either side; surface of upper (left) valve or both, often colored. (Adapted from Dall, Bartsch, and Rehder, Bernice P. Bishop Mus., Bull. 153, 1938, and Olsson, Mollusks of the tropical eastern Pacific, Paleo. Res. Inst.: Ithaca, New York, 1961.) Triassic to Recent, world-wide.

Remarks. — The members of this family have a wide distribution both geographically and geologically. Some swim about freely, others are attached by a byssus and rarely (as in *Hinnites)* they become sessile and irregular in form. Most of the large, coarse, thick shelled forms live in shallow temperate and tropical waters, but thin shelled usually small deep-sea forms occur in depths of at least 4504 meters (2463 fathoms).

Several thousand species of pectens have been described as fossils. About 350 to 400 species are now living in the seas, the greater number in Indo-Pacific waters. The largest forms, with the exception of species of *Patinopecten*, live in tropical marine waters. The valves of many species inhabiting temperate waters tend to be less convex and the ribs more rounded in the northern part of their range.

In some areas pectens live in great numbers. Verco (202) mentioned that off Point Marsden, Australia, at a depth of 33 meters (18 fathoms), for miles the bottom of the sea was covered with scallop shells.

The shape and sculpture of the shells of pectens, usually differing in detail on the two valves, are often quite constant, and, as mentioned by Kautsky (203), species may often be recognized from fragments. Jaworski (204) reported the observation that when riblets arise in the interspaces between the ribs of "*Vola*" [*Pecten s. s.*] they always appear first on the left valve. Dall (1898, pp. 692, 693) pointed out that when ribbing tends to become obsolete, the radial sculpture is retained on the left valve after the right valve has become nearly smooth. Furthermore, that the right anterior ear usually, is the last to lose its radial sculpture.

An interesting characteristic of the sculpture of these bivalves is that rarely, if ever, do they possess concentric ribbing although some species such as *Chlamys (Swiftopecten) swiftii* Bernardi and *C. condylomatus* Dall have concentric thickening and undulations or "ledging" (205) of the shell and others have coarse annular growth lamellae such as are present in the subgenus *Camptochlamys* Arkell. The effect of environment or other causes on the shell was well expressed by Arkell (206) who stated, "The Pectens are forms with definite and rather delicate ornament, by which small evolutionary changes may be sensitively registered." The geologic range of supraspecific units as well as of species is frequently short. Furthermore, apparently because of the composition and microstructure of the shell (which is made up of irregular foliated layers of calcite with a thin median prismatic layer of aragonite), pectens often occur abundantly as fossils where other mollusks (except some other genera such as *Ostrea)* are represented only by casts and moulds. From a consideration of the features here enumerated in connection with pectens, it is obvious why this group has furnished some of the most reliable index fossils used in deciphering the age and correlation of strata.

A striking feature of the Tertiary Pectinidae, as pointed out by Davies (207), is the great increase in size during Miocene time. Most specimens from strata of Eocene or Oligocene age do not exceed 50 mm in diameter. Very large species described from the late Tertiary are: *Mizuhopecten kamagai* Nagasawa, probably of Pliocene age, in Japan, 280 mm long; *Pecten dregeri* von Teppner of Miocene age in Austria, 240 mm long; *Pecten healeyi* Arnold in the San Diego Formation, Pliocene, 222 mm long; and *Chlamys (Nodipecten) arnoldi* Aguerrevere, of late Miocene or Pliocene age in Venezuela, 218 mm long. The greatest size reported for a living species is that of *Pecten (Patinopecten) caurinus* Gould, 288 mm long and 198 mm high.

The shells of scallops were known to the ancient inhabitants of Europe. Pecten shells, found in caves in Europe, were used as receptacles for mixing pigments by artists of the late Paleolithic age. Pectens were known to the ancient Greeks and Aristotle studied the sense organs of some Aegean species. They were also known to early Amerindians as evidenced by Toltec carvings in the temple of Quetzalcoatl in Teotihuacán near Mexico City. The role of pecten shells in art has been mentioned by Bearl (208). A book (209) published by the Shell Oil Company contains an extensive account of the history of pecten shells in the fields of history, literature, art, anthropology and industry. A scallop *(Pecten purpuratus)* reported in that work, an artifact from Chile, was dated at about 3000 B. C.

Some living species of this family especially valuable as food, have received intensive study. An interesting feature of the shell is the presence of concentric rings formed by offsets, or by color changes, during growth, and best observed on the upper valve. These rings according to Risser (210) and Gutsell (211) are a result of a quiescent period of growth during the spawning season. It is generally believed that these rings are formed annually, but this is not always the case because, as pointed out by Gutsell, rings sometimes are present on young shells which have not reached maturity. Davenport (212) discussed the significance of growth lines in fossil pectens as indicators of past climates.

Bazikalova (213) concluded from a study of *Pecten yessoensis* Jay that the rings on the valves are not reliable indicators of age. He stated that the dark rings on the whitish-yellow ground of the ligamental pit were formed annually. These he believed to be reliable indicators of the age of scallop shells as borne out by application of this method to *Chlamys laeta [C. nipponensis* Kuroda] and *C. swifti* as well as to *P. yessoensis.*

About 145 supraspecific units have been proposed for members of this family. Many of these have little or no taxonomic value and in some cases their use obscures interregional relationships, as shown by Fleming (214) in his studies of *Pecten* in the western Pacific region.

Many publications, only a few of which will be mentioned here, deal with scallops because of their importance and their use as guide fossils in correlation of strata and because of the commercial value of some species

for food.

Jackson (215) discussed the phylogeny of the Pectinidae and pointed out that they originated from a *Pteria*-like form. Philippi (216) also discussed their phylogeny and emphasized "Iteration," the similarity of shell characters which appear again and again at different times and places in species which may not be closely related. Verrill (217) in 1897 discussed the characters and classification of the Pectinidae and the same year Sacco (218) presented a classification of the Tertiary genera and subgenera of the Mediterranean region. This was followed in 1898 by Dall (219) who reviewed the genera and subgenera of Tertiary pectens and included a review of west American Tertiary species.

A catalogue of Tertiary species and genera was published by von Teppner (220) in 1922. A number of genera and subgenera were proposed later for the New Zealand groups by Marwick (221) in 1928, for the Recent Hawaiian species by Dall, Bartsch and Rehder (222) in 1938, and for the Recent Australian species by Iredale (223) in 1939. A number of genera proposed by Iredale have been applied to Japanese species by Habe (224).

A catalogue by Rowland (225) containing supraspecific nomenclatural units of Tertiary Pectinidae appeared in 1938.

The Cenozoic species of Pectinidae of western United States were described and illustrated in an excellent monograph by Ralph Arnold (226). A number of species from late Tertiary strata in Lower California, Mexico, were described by Hertlein (227), E. K. Jordan and Hertlein (228), and by Durham (229). Tertiary species from the eastern United States have been well illustrated and described by Tucker-Rowland (230) and by Mansfield (231).

Key to Genera and Subgenera of Pectinidae

A. Right valve with very slight or no byssal sinus

- a. Right valve highly convex, beak curved over hinge line . . . . . *Oppenheimopecten*
- aa. Right valve moderately or only slightly convex, beak not decidedly curved over hinge line.
  - b. Right valve moderately convex, ribs often coarse and wide; left valve flat or concave, often with a depressed area beneath beak . . . . *Pecten s. s.*
  - bb. Right valve gently convex, ribs usually low, numerous; left valve flat or plano-convex, no depressed area beneath apex . . . . . *Flabellipecten*

B. Right valve with well-developed byssal sinus

- a. Shell usually not exceeding 10 mm in height; no external ribs but with very fine threads or radial rows of spines or pustules . . . . . *Cyclopecten*
- aa. Shell exceeding 10 mm in height; external ribs present.
  - b. Valves with about five coarse major ribs . . . . . *Swiftopecten*
  - bb. Valves with more than five major ribs.
    - c. Hinge line as long as valves or nearly so, often oblique, shell small, thin . . *Leptopecten*
    - cc. Hinge line shorter than valves; often large, thick.
      - d. Both valves rather flattened; very large, subcircular.
        - e. Ribs on left valve narrow, rounded . . . . . *Patinopecten*
        - ee. Ribs on left valve narrow to wide, high with frill-like flanges . . . . . *Lituyapecten*
      - dd. Both valves moderately or highly convex.
        - f. Valves covered with well-developed, even, radial striae; hinge with prominent cardinal crura or teeth . . . . . *Lyropecten*
        - ff. Valves with spinose or imbricating sculpture; hinge with fine (or no) crura.
          - g. Adult right valve attached to substrate . . . . . *Hinnites*
          - gg. Adult right valve not attached to substrate.
            - h. Left valve deeper than right; usually with spinose or imbricating sculpture; anterior ear usually longer than posterior one . *Chlamys s. s.*
            - hh. Right valve deeper than left; often with imbricating but no spinose sculpture; anterior and posterior ears nearly equal in length . . . . *Argopecten*

A classic monograph of Neogene pectens of Europe begun by Depéret and Roman (232) was completed by Roger (233). A recent paper by Eames and Cox (234) deals with Tertiary pectens of Persia and the Mediterranean region and a paper by Csepreghy-Meznerics (235) discusses the Neogene Pectinidae of Hungary.

The work of Grant and Gale, 1931, concerning west American species, and some of the papers of Masuda containing discussions and illustrations of Tertiary species of Japan will be mentioned in the present paper in the discussions of the species. Masuda (236) recorded and discussed 136 species and subspecies from the Tertiary of Japan, divided into twenty genera and six subgenera. A recent paper by MacNeil (237) deals with northern Cenozoic pectinids.

Recent west American Pectinidae have been discussed by Hertlein (238) and by Grau (239). Recently Olsson (240) described a new species from Peru.

Through the courtesy of Dr. F. K. North (241), a copy of a manuscript by him containing an excellent discussion of the supraspecific units of the Pectinidae was available for consultation.

A systematic arrangement of the supraspecific groups of the Pectinidae by the senior author appeared recently in "Treatise on Invertebrate Paleontology" (Part N, Vol. 1, pp. N348-N373, figs. C72-C94, 1969).

GENUS *PECTEN* MÜLLER

Pecten Müller, Zool. Danicae Prod., p. 248, 1776. Nine species cited including *Pecten maximus* Linnaeus. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 689, 1898. "Type *Ostrea maxima* Linné." — Depéret and Roman, Mém. Soc. Géol. France, Paléo., Mém. 26, (Tom, 10, Fasc. 1), pp. 9, 10, 1902. "Type *Pecten jacobaeus* Linné."

Janira Schumacher, Essai Nouv. Syst. Hab. Vers Test. pp. 40, 117, 1817. "pour type de ce genre j'ai donné la figure de la *Janira intermedia* Pl. III. Fig. 4."

Type species (designated by Schmidt, Versuch Conch.-Samml., p. 67, 1818). — *Ostrea maxima* Linnaeus [Syst. Nat., ed. 10, p. 696, 1758. "Habitat in Oceano Europaeo." (References include Lister, Conch., pl. 161, fig. 1; Gaultieri, Test., pl. 98, figs. A. B.; and others). Also illustrated by Reeve, Conch. Icon., Vol. 8, *Pecten*, sp. 38, pl. 9, fig. 38, 1852. — Dakin, Liverpool Mar. Biol. Comm., Mem. 17, *Pecten*, pl. 1, figs. C, D, E, F, 1909. See also discussion of this species by Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art, 1, pp. 163-164, 1952].

Range. — Late Eocene to Recent, worldwide in warm temperate and tropical marine water. Late Oligocene or early Miocene to Recent in western North America and in the Tethyian region; Pliocene to Recent in New Zealand, Australia, East Indies, Philippine Islands and Japan (242). Recent in from 9 to 1846 meters (5 to 919 fathoms).

Description. — Shell suborbicular, often large, inequivalve; right valve convex, the left flat, concave or slightly convex; auricles moderately large, nearly equal, delimited from body of shell, a slight byssal sinus, usually only slightly developed, under the anterior auricle; ctenolium lacking; sculptured with rather broad, square or rounded radial ribs which may bear longitudinal threads or may be nearly smooth, and the whole crossed by fine concentric imbricating lamellae; in some subgenera (such as *Euvola*) the radial sculpture consists of grooves; 2 to 4 pairs of cardinal crura radiate from the top of the ligamental pit; inner margin of ventral portion of valves usually scalloped corresponding to the exterior ribbing.

Remarks. — Deshayes (243) discussed the early usage of the name "*Pecten*" and Lovell (244), Stearns (245), and others have discussed the historic and heraldric significance of certain species of this group of bivalves, especially in Europe.

The usage of the generic name *Pecten* by Osbeck, 1765, accepted by Grant and Gale, 1931, is considered to be a *nomen nudum* by most authors. Reasons for that conclusion are clearly expressed by Stiles (246).

Pectens with convex right and flat or concave left valves occur early in the Jurassic of North and South America, and somewhat similar forms occur in the Mediterranean region. Cox (247) recently reviewed the opinions of some of the earlier authors concerning the classification of Mesozoic pectens. The early Jurassic forms are referable to genera such as *Weyla* J. Böhm (type, *Pecten alatus* von Buch) which possess hinge characters different from modern forms. We are inclined to restrict the use of the genus name *Pecten* to Cenozoic species.

Twenty-four species and subspecies of pectens with concave-convex valves have been described from the late Cenozoic in the region between California and Peru, three of which occur in the San Diego Formation. The earliest representative in this region is *Pecten sanctaecruzensis* Arnold (248) from strata of early Miocene age. This species bears a general resemblance to *P. valentinensis* Fontannes (249), from the Burdigalian, early Miocene of Europe.

Most recent species of *Pecten* can swim freely by clapping their valves together. By expelling the water rapidly from the body cavity, they are capable of executing a series of zig-zag movements, the ventral margin foremost. However, when frightened by an enemy or for any other reason, they can swim backward with the hinge foremost. When at rest they lie upon the right valve on the floor of the ocean. A row of bright eyes occurs along the edge of the mantle and with these organs the scallop can detect light and shadow.

The rate of growth varies with different species. Dakin (250) made an extensive study of *Pecten maximus* and found that shells 86 mm in anterior-posterior diameter were 3 1/2 years old. Fleming (251) mentioned that growth of Recent scallops declines rapidly after three years but that some may attain an age of 22 years. The same author gave an excellent discussion (252) of the western Pacific species of the genus *Pecten* and their interregional relationships.

SUBGENUS *PECTEN* S. S.

Pecten (Pecten) bellus Conrad
Plate 30, Figures 1, 2, 3, 4, 9;
Plate 32, Figure 14; Text figure 7

Janira bella Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, p. 312, December, 1856. Reprint by Dall, U. S. G. S., Prof. Paper 59, p. 173, 1909. — Conrad, U. S. Pac. Rail Road Expl., Vol. 6, Pt. 2, No. 2, p. 71, pl. 3, fig. 16, 1857. "Locality. — Santa Barbara, Cal. — Doctor Newberry." — Orcutt, West Amer. Sci., Vol. 6, whole No. 45, p. 70, July, 1889. "Pacific Beach,"

"Tertiary." — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 55, 1944. Earlier records cited.

Pecten Hemphillii Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 15, 1878. "San Diego." "Later Tertiaries." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 29, 1878. "About ten miles northward from San Diego, on the seacoast of California." — Carson, Pan-Amer. Geol., Vol. 43, No. 4, p. 268, 1925. "San Diego fauna." Pliocene.

Pecten hemphilli Dall, Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., Vol. 7, p. 257, 1888. "Pl. — San Diego." — J. P. Smith, Calif. State Min. Bur., Bull. No. 72, p. 38, 1916. "San Diego and lower Fernando formations of the coastal region of southern California." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 146, 150, 151, 155, 1919. "San Diego," Pliocene. Also "Fernando" and "Santa Maria faunal zone," Pliocene. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 87, 1944. Dall's original record cited. Also others. — Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, pp. 64, 82, pl. 16, figs. 15, 16; pl. 21, fig. 8, 1950. Cebada and Graciosa members of the Careaga Sandstone, Santa Maria district; p. 104, Pacific Beach and inland, San Diego district; p. 106, "San Diego formation." — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. "San Diego formation at Pacific Beach." Also Niguel Formation and localities in southern California and Lower California.

Pecten (Pecten) hemphillii Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 706, 1898. "Found with *P. expansus*" [= *P. healeyi* Arnold]. — Schuchert, Dall et al. U. S. Nat. Mus., Bull. 53, Pt. 1, p. 488, 1905. "Pliocene. San Diego, California."

Pecten (Pecten) hemphilli Dall, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 105, 1903 (as *Pecten hemphilli*, p. 63). "Pliocene. — Pacific Beach and Russ School, San Diego (Hemphill; Dall; Arnold)." — Arnold, U. S. G. S., Prof. Paper 47, pp. 28 (as *P. hemphilli*), 97, pl. 33, figs. 3, 3a, 3b, 1906. "Pacific Beach, Russ School, and 'San Diego well', San Diego," Pliocene. Also in Temescal Canyon north of Santa Monica, California. — Arnold and Anderson, U. S. G. S., Bull. 322, pp. 59, 152 (as *Pecten hemphilli*), pl. 25, fig. 5, 1907. "One mile north of Schumann station", also from "Fernando" of Santa Maria district, Pliocene. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 87, 1944. Arnold's records cited, also others. — Glibert and Van de Poel, Mém. Inst. Roy. Sci. Nat. Belgique, Deuxième Ser., Fasc. 78, p. 19, 1965. Pacific Beach, San Diego, Pliocene.

Pecten (Pecten) bellus Conrad, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 103, pl. 21, figs. 1, 2, 1903. "Pliocene at Santa Barbara, California." — Arnold, U. S. G. S., Prof. Paper 47, p. 95, pl. 31, figs. 1, 1a, 1906. Various localities in late Pliocene of southern California. — Arnold, in Arnold and Eldridge, U. S. G. S., Bull. 309, p. 24, pl. 35, fig. 3, 1907. "Pliocene, Santa Barbara. Also found in Pliocene of Ventura, Santa Barbara, and adjacent Counties." — Arnold, U. S. G. S., Bull. 321, p. 32, pl. 15, figs. 1a, 1b, 1907. "Bathhouse Beach, Santa Barbara." "Packards Hill" (p. 32). — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Sci., Ser. 4, Vol. 15, No. 14 pp. 417, 430, pl. 32, fig. 2; pl. 33, figs. 1 and 2; pl. 34, figs. 2, 3, 4, 1926. "Pacific Beach near San Diego, California", Pliocene. Also other localities in southern California and Lower California.

Pecten bellus Conrad, McLaughlin and Waring, Calif. State Min. Bur., Bull. No. 69, map folio (inside back cover), sp. No. 46, pl. 1, fig. No. 46, 1914. "Fernando of the Santa Clara River Valley, Ventura Co., California." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 152, 1919. "San Diego," Pliocene. Also "Fernando" and "Santa Barbara," Pliocene. — Clark, Stratigraphy and Faunal Horizons of the Coast Ranges of California (Privately Publ.), p. 28, pl. 40, figs. 1, 2, 1929. Middle and Upper Pico, Pliocene (cited as "*Pecten (Pecten) bellus* Conrad" on expl. to plate 40). — Hertlein and Grant, Jour. Mines Geol., Rept. 35 of Calif. State Mineral., p. 69, 1939. Sandstone overlying basal conglomerate, Pacific Beach, Pliocene. — Hanna and Hertlein, Calif. State Div. Mines, Bull. 118, p. 176, fig. 14 (p. 177), 1941. "Base of Santa Barbara sands and marls on trail on northeast slope of Packard's Hill, Santa Barbara, California." "Upper Pliocene". — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, pp. 56, 59, 1944. Upper beds exposed in Pliocene section at Pacific Beach; also near Mexican Boundary 3/4 mile from the sea. — Hertlein and Grant, Calif. State Div. Mines, Bull. 70, Chapt. 2, p. 60, 1954. San Diego Formation, Pliocene. — Milow and Ennis, 57th Ann. Mtg. Cordilleran Sec., Geol. Soc. Amer., Field Trip Guidebook — 1961, San Diego Co.,1961, p. 28. "San Diego formation."

Pecten (Janira) bellus (Conrad) variety *hemphilli* Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 226 [not all the synonymy], pl. 3, figs. 1a, 1b, 1931. "Middle Pliocene at Pacific Beach, San Diego." Also other localities.

Pecten bellus hemphilli Dall, Woodring, Stewart, and Richards, U. S. G. S. Prof. Paper 195 (table opposite p. 112), 1941. "Strata at Pacific Beach." Also mentioned, p. 111.

Pecten (Pecten) bellus hemphilli Dall, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 50, pl. 23, figs. c, d, 1968. San Diego Pliocene. Also other localities.

Type specimen. — Originally in Academy of Natural Sciences of Philadelphia. Specimen now missing.

Neotype specimen (designated by Stewart, Acad. Nat. Sci. Philadelphia, Spec. Paper No. 3, p. 117, 1930. "The specimen described and figured by Arnold (1906, p. 95, pl. 31) is taken for the neotype of this species." "Pliocene, Santa Barbara, Cal."). — No. 960, Academy of Natural Sciences of Philadelphia.

Type locality. — "Locality. — Santa Barbara, Cal. Doctor Newberry."

Range. — Middle and late Pliocene; southern California and northern Lower California. Santa Cruz Island, California; Cedros Island, Lower California.

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 104, 105, 547, 957, 1130, 1138, 1178, 1199, 1400, 1402, 2020, 28453, 28644, 28884, 28886, 28889, 28892, 31356, 1141, 1155, 1176, 1177, 36599. L.A.M. 107, 122, 124, 127, 180, 302, 205, 305A, 308, 309, A-2081. S.D. 20, 23, 29, 37, 150, 413, 417. S.D.S.C. 31, 32, 47. U.C.L.A. 296, 307, 1382, 1386, 2420.

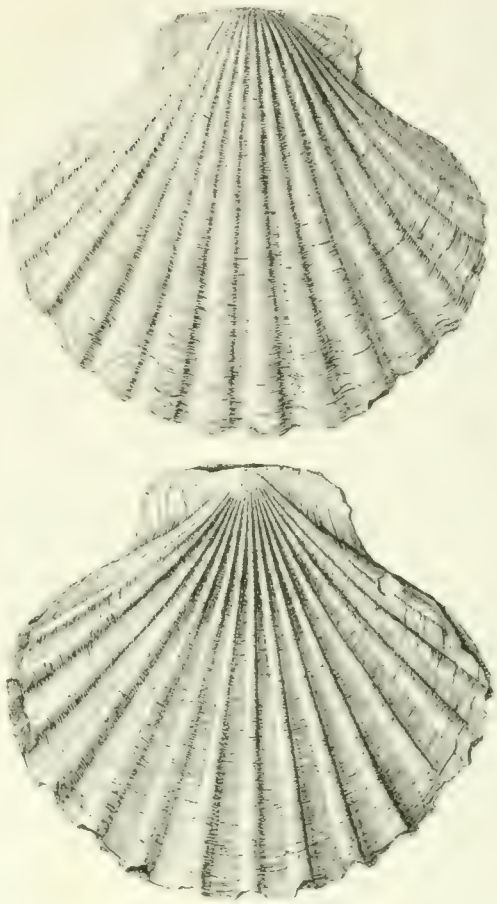
Original description. — Subtriangular; inferior valve convex, ribs 14 or 15, square, about as wide as the intervening spaces, very prominent, some of them with one or two longitudinal obsolete lines; disk finely wrinkled concentrically; upper valve flattened, deeply depressed toward the apex; ribs rather narrower than those of the opposite valve, obscurely bicarinated above, disk ornamented with close, fine, squamose, concentric wrinkles. Length 4 inches; height 3 3/4 inches. (Conrad.)

Description of neotype. — Shell large, thin, inequivalve, elegantly, radiately ribbed. Left (upper) valve slightly convex, the point of greatest convexity being generally about one-fourth the distance from the apex toward the ventral margin; between this point of greatest convexity and the apex there is a deeply depressed area, the depression generally not affecting the two outer ribs on each side, which inclose the depression on the sides; surface of left valve ornamented with 13 or 14 prominent, flat-topped, sometimes faintly bicarinated, radiating ribs, which have flat, sloping sides; these ribs become broader, less elevated, and less sharply angulated near the periphery in the adult; interspaces slightly wider than the tops of the ribs, with slightly rounded bottoms; whole surface of left disk covered with fine, sharp, concentric, regular lamellae; ears rather small, subequal, slightly concave, finely concentrically lamellated, separated from the disk by an impressed line. Right (lower) valve prominently convex, the point of greatest convexity being about one-third the distance from the apex to the ventral margin of the disk; the umbo in this valve curves sharply and meets the plane of the ears at an angle of about 90 degrees; surface of right valve ornamented by 14 or 15 prominent, nearly flat-topped, square, radiating ribs, some of them with one or two longitudinal obsolete lines; the ribs become somewhat less elevated and the sides more sloping as the periphery is approached in the adult; surface of right disk ornamented with close, fine, squamose, concentric wrinkles; ears subequal, arched, covered with crowded, elevated lamellae; byssal notch small. Alt. 80 mm.; lat. 108 mm.; diam. 32 mm.; length of hingeline, 45 mm. (Arnold.)

Remarks. — Fossils here referred to *Pecten bellus* occur at nearly every locality where Pliocene fossils are found in the San Diego area.

We have examined over 600 specimens, the greater number single valves, varying in size from 8 mm to 78.8 mm high. The number of ribs vary from 12 to 18 but the average is about 15. The ribs on the ventral portion of large forms tend to become broad, flat-topped, the sides slope rather steeply to the interspaces. The ribs on smaller specimens are higher, narrower and more rounded. The tops of ribs on large specimens sometimes bear one or more faint longitudinal grooves. The ribbing on the interior of valves, which is well defined on the right valve, extends to the umbonal area, on the left valve to the muscle impression. Low flanges are present on the ribs near the ventral margin of large valves. There are usually two pairs of rather weakly developed cardinal crura but these are not prominent. Auricular crura are well developed on the left valve but less pronounced on the right valve.

Pecten hemphillii Dall was described from beds of Pliocene age at San Diego and compared with *Pecten stearnsii* rather than with *Janira bella* Conrad. Several authors have considered *P. hemphillii* and *P. bellus* to represent the same species. E. K. Jordan and L. G. Hertlein accepted this viewpoint. Grant and Gale cited *P. hemphillii* as a variety of *P. bellus* and stated (p. 886, pl. 3, fig. 1a), "This variety is practically indistinguishable from the typical variety." Woodring, in a recent paper (1950), considered the two forms to be closely related but separable, with *P. hemphillii* being smaller and not exceeding 60 mm in height. We have had available for study five specimens collected by Henry Hemphill and labelled by him "*Pecten hemphillii* Dall. Original lot. Pacific Beach, Cal. San Diego." The largest of these, No. 526a (Calif. Acad. Sci. Dept. Geol. Type Coll.), is 88 mm long, 78.8 mm high, convexity (both valves together), 24 mm. The ribs at the ventral margin are 7.5 mm wide (see plate 30, figures 4 and 9). This specimen, in all shell characters, is similar to specimens of *P. bellus* collected by Tom Dibble at Packard's Hill, Santa Barbara, California, and by others in that area.



Text Fig. 7. *Pecten (Pecten) bellus* Conrad. Hypotype (Cat. No. 2408, University of California at Los Angeles), from Pacific Beach, San Diego; Pliocene. Length 63 mm. A. Right valve. B. Left valve. (Drawn by E. H. Quayle.)

The other four specimens from the original lot of *P. hemphillii* vary as to the width of the ribs. Two show a decided widening toward the ventral margin, the ribs of the other two remain quite narrow and with vertical sides for their entire length. A large right valve collected by G. P. Kanakoff at Loc. 107 (LAM) at the end of Arroyo

Drive, San Diego, is 86 mm long and 77.5 mm high. This specimen in ribbing and other shell characters resembles *P. bellus*. It is true that very large specimens from strata of late Pliocene age at Santa Barbara and other localities attain a greater size. Conrad's type specimen was described as 4 inches (approximately 101 mm) long, and Gabb's specimen illustrated by Arnold and designated as a neotype by Stewart is 108 mm long and 80 mm high. The largest specimen from the San Diego Formation observed by us is 88 mm long and 78.8 mm high. Arnold stated that specimens to a height of 20 mm are hardly separable into two species. A study of the specimens before us seems to indicate that the chief difference between *P. bellus* and *P. hemphillii* is that the former may attain a greater size. However, large specimens from the San Diego Formation apparently do not differ in any constant shell characters from *P. bellus*. We therefore agree with the conclusion of E. K. Jordan and Hertlein who considered *P. bellus* and *P. hemphillii* specifically identical, and stated concerning the latter, "The type of *P. hemphillii*, as indicated by the illustration furnished by Arnold, is an intermediate form not exactly similar to either extreme of the series, although it inclines toward the narrow-ribbed variants."

This opinion is supported by the observations of Druckerman (253) who examined more than 80 specimens of the *P. bellus-hemphillii* series. These varied from 19 to 130 mm in length, average 57 mm; 17 to 99 mm in height, average 51 mm; umbonal angle 89° to 107°, average 97°; right valve with 12 to 17 ribs, average 15; left valve with 11 to 16 ribs, average 14. He concluded that "as the relations of the two forms remain moot, they are arbitrarily placed in synonymy."

Two specimens from Pliocene strata on the east coast of Lower California were illustrated by Durham (254) under the name of *P. bellus* var. *hemphilli*. The right valve, 77.5 mm long (incomplete), differs from *P. bellus* in the proportionately larger and only slightly convex ears and in the general character of the radial ribs. The left valve, 126.5 mm long, with traces of a midrib in the interspaces and finely radially sculptured ears is not typical of *P. bellus* but somewhat resembles the corresponding valve of one of the *P. bakeri* group, perhaps *P. bakeri diazi* (255). Vokes (256) mentioned the occurrence of a fossil form which he considered to be an undescribed subspecies of *P. bellus* bearing 22 ribs from the Infierno Formation of late Pliocene age in the Santa Rosalía area, Lower California.

The species described as *Pecten (Pecten) auburyi* Arnold (257) appears to be only a variant of *P. bellus*. We have examined a paratype, a right valve, slightly distorted (No. 78, Calif. Acad. Sci. Dept. Geol. Type Coll.), from the type locality in Puente Hills in Los Angeles Co. It is 47.6 mm long and 41.8 mm high. It has rather narrow ribs similar to those on the earlier stages of *P. bellus* and is inseparable from some forms labelled *P. hemphillii*.

Pecten (Pecten) lecontei Arnold (258) described from Cedros Island, Lower California, is quite distinct from *P. bellus* and its variants. The ribs, about 18 on the right valve and 17 on the left, are round-topped. Those on the right valve usually quite smooth, separated by flat-bottomed interspaces which are narrower than the ribs. The left valve is usually slightly concave and the rounded ribs are quite different from the high usually flat-topped ribs of *P. bellus*.

Pecten (Pecten) slevini Dall and Ochsner (259) described from strata of Pliocene age on the Galápagos Islands differs from *P. bellus* and its variants by the narrower, rounded ribs on the right valve which are separated by wider interspaces, and by the wider apical angle. The specimen which Grant and Gale (260) illustrated as *P. bellus* var. *slevini* from beds of Pliocene age in Los Angeles Co. appears to be quite different from the type of *P. slevini*, the chief feature of similarity being the wide apical angle. It is probably a distorted specimen of *P. bellus*. Illustrations of *P. archon* Maury (261) bear a resemblance to *P. slevini* but that Miocene Caribbean species has fewer ribs, which on the right valve are shallowly bifid toward the ventral margin.

The shell of *Pecten bellus* bears a general resemblance to that of *P. albicans* Schröter (262) and to *P. excavatus* Anton (263), which have fewer ribs, but close relationship with these Japanese species has not been demonstrated.

Some authors have suggested that *Pecten bellus* could be placed in the supraspecific group named *Notovola* by Finlay. Fleming (264), however, stated that *Notovola* "has no phylogenetic unity," that relationship exists between relatives of the type species, *P. novaezelandiae* Reeve, and the Mediterranean species *P. jacobaeus* which is referable to *Pecten s. s.* and that Finlay's genus is an unwarranted supraspecific unit.

SUBGENUS *FLABELLIPECTEN* SACCO

Flabellipecten Sacco, Bol. Mus. Zool. e Anat. Comp. (Torino), Vol. 12, No. 298, p. 102, June 11, 1897. — Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 24, p. 55, December, 1897. "tipo *F. flabelliformis* (Br.)." — Depéret and Roman, Mém. Soc. Géol. France, Paléo., Tom. 18, Fasc. 2 (Mém. No. 26 (suite), p. 105, 1910. — Cossman and Peyrot, Act. Soc. Linn. de Bordeaux, Vol. 68 (Conch. Néogéne l'Aquitaine, Tom. 2, Livr. 2), p. 272, 1914. "(G. -T. *Pecten flabelliformis* Brocchi, Plioc.)." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 159, 1961. "type species by original designation and tautonomy, *F. flabelliformis* Brocchi."

Type species (by original designation). — "*Flabellipecten flabelliformis* (Br.) (tipo del nuovo sottog.)." [= *Ostrea flabelliformis* Brocchi, Conch. Foss. Subapennina, Vol. 2, p. 580, 1814. "Fosile nel Piacentino e in Valle di Andona." Pliocene. Illustrated by Depéret and Roman. Mém. Soc. Géol. France, Paléo., Tome 1, Fasc. 1, (Mém. No. 26 (suite)), p. 139, pl. 19 (Mém. 26, pl. 18), figs. 1, 1a, 2, 1912. "Topotype de l'Astien du Val d'Andona près Asti (Italie)." — Ronchetti, Riv. Ital. Paleo. e Strat., Mém. 5, Pt. 1, p. 30, fig. 10a, b, c, 1952. [Illustration of type specimen.]

Range. — Early Miocene (Aquitanian) to late Pliocene in the Mediterranean region; (265) Miocene (late and perhaps middle) and Pliocene in the Caribbean region; Middle Miocene to Recent in North and Central America.

Description. — Shell large or of medium size and thickness, apical angle wide. Right valve only moderately convex, the umbo slightly incurved; sculpture commonly consisting of numerous, low, often rounded (but occasionally squarish) radial ribs which are smooth on top or occasionally shallowly longitudinally grooved, the ribs

separated by narrower interspaces; ears subequal, a slight byssal notch at the base of the right ear. Left valve flat or plano-convex; the ribs narrower and the interspaces wider than those on the right valve and often bearing an interstitial thread. Exterior of both valves crossed by fine imbricating lines of growth. Hinge with two to four cardinal crura. The radial flutings on the interior extend inward from the ventral margin about one third the length of the valves. (Adapted from Depéret and Roman, and from Olsson.)

Remarks. — *Flabellipecten* differs from *Pecten s. s.* in the less highly arched right valve which is only slightly incurved at the apex, greater apical angle, smaller ears, more numerous and usually lower radial ribs and in that the left valve is flat or slightly convex and lacks a depression in the umbonal region.

Some American species from time to time have been referred to *Flabellipecten.* Toula (266) in 1908 placed *P. gatunensis,* described from beds of Miocene age in Panama, in *Flabellipecten,* and Depéret and Roman in 1912 mentioned that "*Fl. floridus*" [= *P. diegensis* Dall] was a member of the *Flabellipecten* group. Hertlein (1935, p. 303) mentioned the similarity of *P. diegensis* to the European Miocene species, *P. fraterculus* Sowerby, and to the *P. besseri* group, and also called attention to several similar east American species. Recently Olsson (1961, p. 159) placed in this category, *P. gatunensis* and *P. macdonaldi* Olsson, both species of Miocene age in Central America, and *P. sericeus* and *P. diegensis,* Recent west American species. Roger (1939, p. 264) mentioned the great number of species of *Flabellipecten* in the Atlantic region and intimated the possible origin of this group in the Americas.

Species such as *P. gatunensis, P. macdonaldi, P. bösei, P. sericeus,* and *P. diegensis* bear a close resemblance to species assigned to *Flabellipecten* by European authors. *Pecten hawleyi* Hertlein (267), from the early Miocene (Vaqueros Formation) of California, may be a member of this subgenus. Other species such as *P. stearnsii* Dall, *P. carrizoensis* Arnold and *P. beali* Hertlein, described from strata of Pliocene age in southern California and Lower California, differ from the type species of *Flabellipecten* in the fairly high, medially sulcated ribs but they are believed to be allied to *P. diegensis* and should be included in the same supraspecific taxonomic category. Several east American species of late Cenozoic age are members of this same group, including *P. soror* Gabb, from the Miocene of Santo Domingo, *P. soror codercola* Harris, from the late Tertiary of Venezuela, *P. ochlockoneensis* Mansfield and *P. ochlockoneensis violae* Tucker, from strata of Miocene age in Florida and *P. hemicyclus* Ravenel from beds of Pliocene age in South Carolina.

Some of the American species here referred to *Flabellipecten* differ considerably from the type species of *Flabellipecten* in the character of the ribbing and especially in the fewer cardinal crura. These shell characters, however, vary in the numerous fossil forms described from the Mediterranean region which have been assigned to *Flabellipecten.*

This American group could be placed in a new subgeneric category but we hesitate to add another supraspecific unit for these species whose shell characters so closely resemble species of the *Flabellipecten* group. Furthermore, the taxonomic value of such a new subgeneric unit would be questionable, especially if the statement of Depéret and Roman (1910, p. 107) (268) is taken into consideration, that shell characters of some species reveal gradation of *Flabellipecten* into *Pecten s. s.*

Pecten (Flabellipecten) stearnsii Dall
Plate 29, Figures 2, 4; Plate 35, Figure 10; Text Figure 8

Janira florida Hinds, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, December, 1874. (Printed separately March 26, 1874). "well at San Diego," "Pliocene." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. Well at San Diego. — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., Vol. 7, p. 244, 1888. "Pl. — San Diego well."

Not *Pecten floridus* Hinds, 1844 = *Pecten diegensis* Dall, 1898.

Not *Ostrea florida* Gmelin, 1791, a *Pecten.*

Pecten stearnsii Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 14, March 27, 1878. "Later Tertiary of San Diego." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 29, 1878. "About 10 miles northward from San Diego, on the seacoast of California," "(stratum C)". — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 258, 1888. "Pl. — San Diego." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego," Pliocene. — Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, p. 104, 1950. Pacific Beach and inland, San Diego, Pliocene. — Hertlein and Grant, Calif. State Div. Mines, Calif. Jour. Mines Geol., Rept. 35 of State Mineral., pp. 69, 70, 1939. "In the massive yellowish and gray sandstone overlying the basal conglomerate" "at Pacific Beach;" south slope of Mount Soledad, and "Along India Street," San Diego. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 56, 1944. "Pacific Beach," p. 57, "south sloping spurs of Mount Soledad," p. 59, "excavations along India Street, particularly at the corner of Upas Street." — Keen and Bentson, Geol. Soc. Amer. Spec. Papers No. 56, p. 94, 1944. Earlier records cited. — Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1954. "San Diego formation." Pliocene.

Janira dentata Sowerby, Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., Vol. 7, p. 244, 1888 (in part). "Pl. — San Diego well."

Not *Pecten dentatus* J. Sowerby, 1829, nor *Pecten dentatus* G. B. Sowerby, 1835.

Pecten (Pecten) stearnsii Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 706, pl. 26, fig. 5, 1898. "With *P. expansus*" [i.e. "Pliocene of Pacific Beach (lower horizon), near San Diego, California." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, pp. 63 (as *Pecten stearnsii*), 106, pl. 12, fig. 3, 1903. "San Diego (Pacific Beach, lower horizon)." — Schuchert, Dall, et al., U. S. Nat. Mus., Bull. 53, Pt. 1, p. 490, 1905. "Pliocene. San Diego, California." — Arnold, U. S. G. S., Prof. Paper 47, pp. 28 (as *Pecten stearnsii*), 100, pl. 32, figs, 1, 1a, 1906. "Pacific Beach, near San Diego." — Arnold in Eldridge, U. S. G. S., Bull. 309, pp. 242, 244, pl. 35, fig. 2; pl. 36, fig. 4, 1907. "San Diego formation (Pliocene), Pacific Beach, San Diego County." — Arnold and Anderson, U. S. G. S., Bull. 322, pp. 59, 152, pl. 25, figs. 1a, 1b, 1907. "San Diego formation

(Pliocene), Pacific Beach, San Diego County, Cal." — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. San Diego well [Dall's record of "*Janira florida*, Hds."]; p. 56 (as *Pecten stearnsii*, "Pacific Beach.", p. 57 (as *Pecten stearnsii*), "south sloping spurs of Mount Soledad," p. 59 (as *Pecten stearnsii*), "excavations along India Street, particularly at the corner of Upas Street," San Diego. — Milow and Ennis, 57th Ann. Mtg. Cordilleran Sec., Geol. Soc. Amer., Field Trip Guidebook San Diego Co. 1961, p. 28, 1961. "San Diego formation." Pliocene. — Glibert and Van de Poel, Mém. Inst. Roy. Sci. Nat. Belgique, Deuxième Sér., Fasc. 78, p. 21, 1965. Pacific Beach, San Diego, Pliocene (as *Pecten (s. s.) stearnsi*). — Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 48, pl. 22, figs. a, b, 1968 (as *Pecten (Pecten) stearnsi*). Pacific Beach, Pliocene.

Pecten cf. *P. diegensis* Dall, Dall cited by Ellis, in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 63, 1919. Fossil Canyon, about 3 1/4 miles east of Chula Vista and 1 1/4 miles southeast of Bonita. "Upper Miocene." [Pliocene.]

Pecten (Janira) stearnsii variety *stearnsii* Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 223, pl. 3, figs. 1a, 1b (Holser Canyon), 1931. "Pliocene: Pacific Beach, San Diego." Earlier records cited.

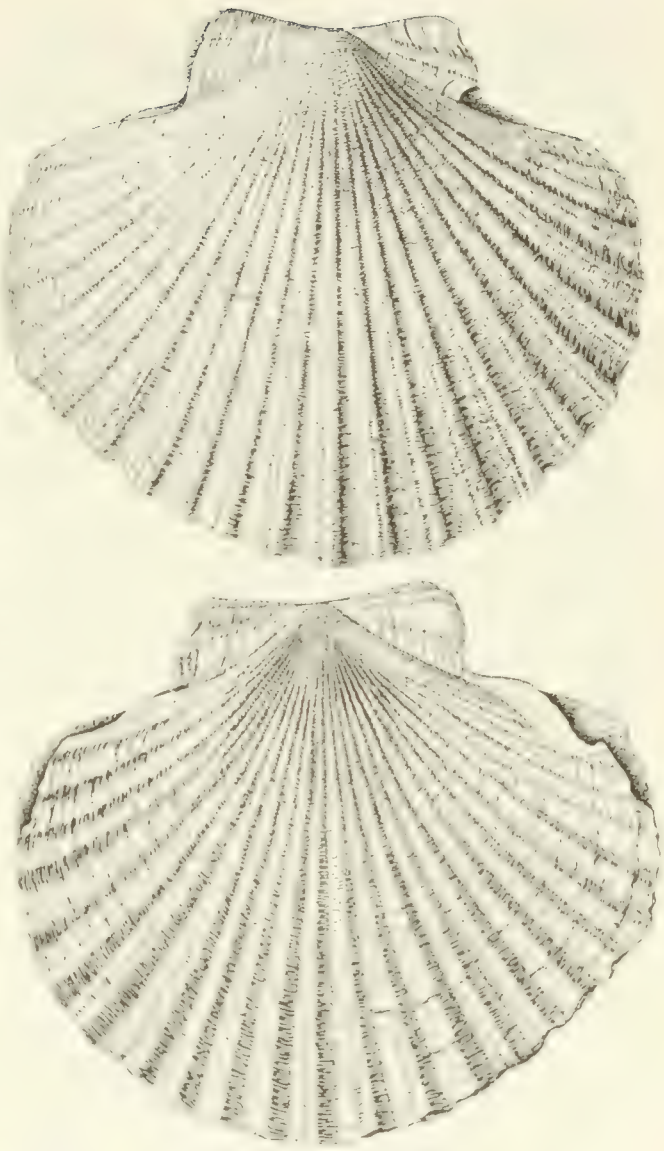
Type specimen. — No. 7942, United States National Museum.

Type locality. — "well at San Diego," California. "Pliocene."

Range. — Middle to late Pliocene (possibly to early Pleistocene).

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 104, 105, 547, 1132, 1138, 1181, 1182, 1183, 1186, 1199, 1399, 1401, 1404, 1413, 1414, 1415, 2015, 28644, 28885, 28889, 28893, 33334, 35025. L.A.M. 107, 121, 122, 180, 305, 309, 1178, A-1323. S.D. 2, 4, 5, 75, 80, 88, 331, 404, 417. U.C.L.A. 294, 295, 299, 300, 312, 2359, 2407, 2420.

Original description. — Shell moderately large, thin, regular; elegantly radiately ribbed. Upper valve flattened or even a little concave, with about twenty-four regularly rounded, vaulted, even ribs, separated by slightly wider channelled interspaces; the whole surface covered with fine, sharp, concentric, regular lamellae, a little looped backward over the top of the ribs, but showing no appearance of reticulation anywhere; ears small, nearly symmetrical, covered with more elevated, crowded, concentric lamellae, especially near the margins; hinge-margin straight, or even a little concave toward the umbo; peripheral margins of the valves strongly and regularly crenulated and interlocking; interior regularly deeply grooved, to correspond with the external ribs; lower valve slightly convex, with about twenty-six regular even ribs, separated by channelled interspaces somewhat narrower than the ribs; the top surface of each rib is flattened with a broad, shallow groove in the middle. with one or two faint riblets on each side of the groove; the whole surface is covered with concentric lamellae, like those of the upper valve, but less sharp, and about twice as crowded. Ears subequal, arched, covered with crowded, elevated lamellae; byssal notch very small. Height of shell, 90 mm; breadth, 100 mm; breadth of hinge-line, 34 mm; thickness, 15 mm. (Dall.)



Text Fig. 8. *Pecten (Flabellipecten) stearnsii* Dall. Hypotype (Cat. No. 2407, University of California at Los Angeles), from Pacific Beach, San Diego; Pliocene. Length 105.6 mm. A. Right valve. B. Left valve. (Drawn by E. H. Quayle.)

Remarks. — This species occurs rather abundantly at various localities including the beds in the upper portion of the Pliocene section at Pacific Beach, also on the south slope of Mount Soledad and on the San Diego Mesa.

Three specimens of the type lot collected by Henry Hemphill bear the numbers 525, 525a, 525b in the series of type specimens in the California Academy of Sciences. The largest of these is 97.6 mm long, 83 mm high, convexity (both valves together), 18.3 mm. A large left valve from Loc. 1401 (CAS), south slope of Mount Soledad is 100 mm long and 85 mm high.

Pecten stearnsii is an extinct species and, as mentioned by Dall and by Arnold, it is the precursor of *P. diegensis* Dall (269), a Recent species which occurs at

the present time in waters off San Diego.

Pecten stearnsii differs from the Recent species in the greater number of ribs, 23 to 26 on the right valve and about 24 on the left valve in comparison to 19-21 on the right valve of *P. diegensis* and 20-21 on the left one. Furthermore, the hinge line of *P. stearnsii* is shorter, the ribs are usually more deeply medially sulcated and the interspaces between the ribs are narrower than those of *P. diegensis*. Woodring, Bramlette, and Kew (1946, p. 80) called attention to the fact that near the margin of the interior of the right valve of *Pecten diegensis* a flange occurs along each edge of the projection corresponding to the interspace on the exterior. Similar flanges appear to be lacking or but slightly developed near the anterior and posterior ends of the right valve of *P. stearnsii*.

The two forms are very similar but in our opinion the differences are sufficient to justify recognition of each as a separate species. Grant and Gale (1931, p. 223) and Woodring, Bramlette, and Kew (1946, p. 80) considered *Pecten diegensis* to be a subspecies of *P. stearnsii*. *Pecten lunaris* Berry (270), a Recent species described from the Gulf of California, is a member of this group.

Pecten sericeus Hinds (271), a Recent species originally described from Panama, differs from *P. stearnsii* and *P. diegensis* in that the ribs, especially toward the ventral margin on adult right valves, often develop a low, median, tricarinate ridge.

Three fossil forms of Pliocene age in the Gulf of California region are closely allied to *P. stearnsii*.

Pecten carrizoensis Arnold (272) described from strata of Pliocene age in eastern San Diego County, has fewer (18 or 19 on right, 17 on the left valve) and less prominent ribs, which are separated by narrower interspaces than those on *P. stearnsii*.

Pecten beali Hertlein (273) described from strata of Pliocene age on the east coast of Lower California, differs from *P. stearnsii* in that the ears of the right valve bear radial riblets and in that a fine radial riblet occurs in each interspace between the radial ribs on the left valve. *Pecten ochlockoneensis violae* Tucker (274) from beds of Miocene age in Florida is an allied species.

Pecten bösei Hanna and Hertlein (275), described from beds of Pliocene age on the east coast of Lower California, differs from *P. stearnsii* in possessing lower, nonsulcated, often almost smooth ribs. Specimens from Pliocene beds in the Gulf of California region referred to *P. stearnsii* by Hanna and Hertlein (1927) are not typical of that species, but are more nearly allied to *P. bösei*. Vokes (276) cited a species under the name of "*Patinopecten* cf. *stearnsii*" from the Gloria Formation of Pliocene age on the east coast of Lower California.

Pecten soror Gabb (277), described from beds of Miocene age in Santo Domingo and *Pecten soror codercola* Harris (278), described from late Tertiary strata in Venezuela, apparently are members of the *P. stearnsii* group.

Pecten stearnsii occurs rather commonly in beds of middle and late Pliocene age along the coastal region of southern California from Ventura County to San Diego and along the west coast of northern Lower California, at Cedros Island, Turtle Bay, and elsewhere on the peninsula and at Maria Madre Island, Tres Maris Islands. We have not seen typical specimens of *P. stearnsii* from strata other than of Pliocene age. However, the specimens illustrated by Woodring, Bramlette, and Kew (1946, pl. 32, figs. 14, 15), from unit 1 of the Timms Point silt at San Pedro, appear to be referable to this species. Those authors considered this silt to be of Pleistocene age but many authors earlier considered it to be of late Pliocene age.

Pecten stearnsii is allied to *P. diegensis*. The former species may have occupied habitats similar to *P. diegensis*, which lives in west American waters from Cordell Bank, off central California, to Gorda Bank, off Cape San Lucas, Lower California, Mexico. The bathymetric range of *P. diegensis* given by Grau is 9 to 366 meters (5 to 200 fathoms). According to Fitch (279) "This scallop usually swims a few feet off the bottom in rocky areas from five to seventy-five fathoms beneath the surface." It occurs in beds of Pleistocene age in southern California.

SUBGENUS *OPPENHEIMOPECTEN* VON TEPPNER

Oppenheimopecten von Teppner, Fossilium Catalogus 1: Animalia Pars 15, Anisomyaria II, p. 254, 1922. — von Teppner, quoted in Roger, Mém. Soc. Géol. France, Nouv. Sér., Tome 17, Fasc. 2-4, Feuilles 7-43, Mém. No. 40 (suite et fin du Mém. de Paléo., No. 26 et du Mém. N. S., No. 10), p. 242, 1939. Type *P. subbenedictus* Fontannes. — Grau, Allan Hancock Pac. Exped., Vol. 23, p. 148, 1959. Type *Pecten subbenedictus* Fontannes.

Convexopecten Tucker-Rowland, Jour. Conch., Vol. 21, No. 3, p. 82, September 22, 1938. "with genotype *Pecten (Convexopecten) josslingi* (Smith), Quart. Jour. London Geol. Soc., 3:419, pl. XVI, figs. 10-12, 1847."

Type species (by original designation, von Teppner, 1922, p. 254). — "Typus: *Pecten (Oppenheimopecten) subbenedictus* Fontannes." [*Pecten subbenedictus* Fontannes, Etudes stratigraphiques et paléontologiques pour servir à l'histoire de la période tertiare dans le Bassin du Rhône: III, le Bassin de Visan (Vaucluse), (Lyon), p. 83, pl. 2, fig. 1, 1878. — Depéret and Roman, Mém. Soc. Géol. France, Paléo., Tome 10, Fasc. 1, Mém. No. 26, p. 39, pl. 5, figs. 1, 1a, 2, 1902. Southern France, Burdigalian, Miocene.]

Range. — Early Miocene (Burdigalian) to Recent. Recent in Indo-Pacific, Australia, Japan, Hawaii, and in the eastern Pacific, in shallow tropical and subtropical waters.

Original description (translation). — Inequivalve, right valve strongly convex (umbo strongly incurved) with rounded ribs, broader than the interspaces. Ears large, unequal. Ribs of left valve flat and broad, narrower than the interspaces. Concentric sculpture of right valve very weak, the left distinct. (Translation by Grau of von Teppner's original description in Roger.)

Remarks. — The most characteristic feature of this subgenus is the very highly convex right valve with incurved umbo overhanging the left valve. The left valve may be nearly flat or shallowly to moderately concave.

In the Mediterranean region, *Oppenheimopecten* is represented by perhaps fifteen or more species and subspecies described from strata of Miocene and Pliocene age. In the eastern Pacific this subgenus is represented by eight species, *P. juanensis* Grant and Eaton in the late Miocene, *P. coalingaënsis* Arnold in Anderson, *P. hartmanni* Hertlein, and *P. heimi* Hertlein in the Pliocene, and the

Recent species, *P. galapagensis* Grau, *P. hancocki* Grau, *P. perulus* Olsson and *P. vogdesi* Arnold. In the Indo-Pacific region, *Oppenheimopecten* is represented from Pliocene to Recent, including Recent species such as *P. erythraeensis* Sowerby, *P. fumatus* Reeve, *P. albus* Tate and *P. excavatus* Anton.

Fleming (280) gave an excellent discussion of the members of the *Pecten benedictus* group (referable to *Oppenheimopecten*), in New Zealand and Australia.

Pecten (Oppenheimopecten) vogdesi Arnold
Plate 29, Figures 1, 3, 5, 6

Pecten dentatus Sowerby, Proc. Zool. Soc. London for 1835, p. 109, October 9, 1835. "Hab ad Sanctam Elenam." "Found among sand and stones in twelve fathoms." — Sowerby, Thes. Conch., Vol. 1, p. 49, pl. 15, figs. 105, 106, 1842.

Not *Pecten dentatus* J. Sowerby, 1829. Fossil in Great Britain.

Pecten excavatus Valenciennes, Zool. Voy. Venus, pl. 19, figs. 1, 1a, 1b, 1c, 1846. [No description or locality.]

Not *Pecten excavatus* Anton, 1839. China.

Janira dentata Sowerby, Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 28, 1878. "Well" at San Diego. — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 244, 1888. [Quaternary records only according to Arnold, 1906.] — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 86, August, 1889. Dall's record (1878) cited. — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 60, 1919. Dall's record (1878) cited.

Pecten (Pecten) dentatus Sowerby, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 104, pl. 12, figs. 1, 1a, 1903. Pleistocene and Recent. P. 105, "Pliocene. — San Diego well (Cooper) — (Probably *P. hemphilli*)."

Pecten (Pecten) vodgesi Arnold, U. S. G. S., Prof. Paper 47, p. 100, pl. 33, figs. 1, 1a, pl. 34, fig. 1, 1906. "The type of this species (a right valve) is from the upper San Pedro formation at San Pedro," California, Pleistocene. Also cited from "Pliocene (?). San Diego (Hemphill); Cholas Valley near San Diego (Stearns)." — Arnold in Eldridge, U. S. G. S., Bull. 309, p. 242, pl. 35, fig. 5 (Pleistocene, Ventura County), 1907. "Also occurs in supposed Pliocene near San Diego." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 158, pl. 20, figs. 4, 4a, 4b, 1961. Range: Magdalena Bay, Lower California, Gulf of California to Panama.

Pecten (Euvola) cataractes Dall, Nautilus, Vol. 27, no. 11, p. 121, March, 1914. "For this common species of the Gulf of California I propose the name of *Pecten (Euvola) cataractes.*"

Pecten (Janira) vogdesi Arnold, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 228, pl. 3, figs. 3a and 3b (Recent, Gulf of California), 1931. "Pliocene: 31st Street and Logan Avenue, San Diego (Sternberg Collection, 1924, specimen at Stanford University)." Earlier records cited.

Pecten (Oppenheimopecten) vogdesi Arnold, Grau, Allan Hancock Pac. Exped., Vol. 23, p. 149, pl. 55, 1959. Pliocene to Recent. Recent, Punta Eugenia, Lower California, to the Gulf of California and South to Paita, Peru.

Type specimen. — No. 4 Stanford University, Department of Geology. Type Collection.

Type locality. — "from the upper San Pedro formation at San Pedro", Los Angeles County, California; Pleistocene.

Range. — Middle Pliocene to Recent. Recent from Punta Eugenia, western Lower California, Mexico, to the head of the Gulf of California and south to Panama, in 4 to 219 meters (2 to 120 fathoms) (Grau). "Usually found in sand, sandy mud, or mud bottom, associated with coral, coralline or sponge." (Grau.)

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 1137. L.A.M. 320, 320A, P.87: No. 8325. S.U. Same locality as C.A.S. 1137.

Original description. — Shell similar to *P. excavatus*, except averaging larger and with the following differences: Right valve, somewhat less convex, has 19 or 20 broader, flatter ribs, which are separated by relatively broader interspaces that occasionally show faint intercalary riblets or faint longitudinal striations. Left valve with fewer ribs than *P. excavatus*, and having no intercalary riblets, or faint ones, which become obsolete near the periphery of the disk; ears slightly less concave than in *P. excavatus*. (Arnold.)

Dimensions. — Alt. 69 mm; hinge line to ventral margin (right valve) 67 mm; long. 73 mm; hinge line 35 mm; diameter 24 mm; umbonal angle (left valve) 98°. (Arnold.)

Remarks. — This species was recorded from the San Diego well by Dall and by Cooper. Arnold (1906) did not refer to Dall's record (1878) of this species from the San Diego well, but he did mention that Cooper's record (presumably based upon that of Dall) of "*Janira dentata*" was in part referable to *P. stearnsii*. Whether or not Dall's record should be referred to *P. stearnsii* is unknown to us. Arnold mentioned that specimens of this species were collected by Stearns from beds of Pliocene age in Las Chollas Valley and that others were collected by Hemphill in San Diego in strata of probable Pliocene age.

One right valve and three left valves in the collections of the California Academy of Sciences, were collected by Charles Sternberg from 31st Street near 32nd Street and Logan Avenue, San Diego. One right and one left valve from the same locality are in the collections of Stanford University. One right and two left valves from 32nd and Woolman streets, San Diego, are in the collections of the Los Angeles County Museum. One of the left valves is 110 mm long and 90.5 mm high. Additional specimens were collected by Kanakoff at Locs. 320 and 320A, and at 835, 32nd Street, San Diego.

These specimens occur in fine, hard, gray, cemented sandstone. Some of them are of a reddish-brown color. The largest, a left valve from Loc. 320A, is 111.5 mm long and 86.9 mm high. According to Kanakoff, these specimens, along with specimens of *Pecten circularis* and other species embedded in hard matrix, occur in beds definitely referable to the San Diego Formation. Above this bed is a layer about a foot thick containing abundant *Chione californiensis* and *Lucina nuttalli*. The preservation of the *Chione* and the lithology of the reddish-brown bed are clearly not referable to the San Diego Formation.

The observable shell characters of the Pliocene *P. vogdesi* do not differ from Recent specimens. On some left valves the interspaces lack a radial riblet but on others it

is present. This feature varies in both fossil and Recent specimens. The hinge of juvenile specimens has but one pair of crura but adults have two pairs.

Pecten (Pecten) heimi Hertlein (281) described from strata of Pliocene age in Lower California is a similar species but that it is identical with *P. vogdesi*, as believed by Grant and Gale, is open to question. The ears of the type specimen are weakly sculptured and the ears of the left valve are smooth, whereas the ears of Recent *P. vogdesi* are ornamented with well defined riblets.

Pecten (Pecten) juanensis Grant and Stephenson (282), described from beds of late Miocene age in San Luis Obispo County, California, has smooth ears and the apical angle is about 90° rather than 95° to 100° in *P. vogdesi*. Grant and Stephenson suggested that *P. juanensis* might be the precursor of *P. coalingaënsis* Arnold in Anderson (283), and *P. vogdesi*.

Pecten (Oppenheimopecten) hancocki Grau (284), a Recent species from Cocos Island, has only 16 to 17 ribs and the right valve is much less convex than that of *P. vogdesi* and it differs in other details.

In general appearance *P. vogdesi* bears a general resemblance to some members of the *P. benedictus* group and especially the *P. aduncus* group (285) in the Miocene of the Mediterranean region but there are differences in the shape of the ribs and in other details.

Except for its occurrence in the San Diego Formation, *Pecten vogdesi* has been reported from southern California only in beds of Pleistocene age. It is known to occur in beds of Pliocene and of Pleistocene age in the Gulf of California region as well as in Pliocene strata at Maria Cleofa Island, Tres Maris Islands, and in beds of Pleistocene age at Magdalena Bay, Lower California. It also has been reported from beds of Pleistocene age along the coast of Panama and Ecuador. This interesting species has been taken at many localities in the Gulf of California.

The range of Recent *P. (O.) vogdesi* usually cited in the literature, is from the Gulf of California to Paita, Peru. Olsson recently mentioned that this species does not occur south of Panama and that he observed no specimens from south of Mexico. He described a species from Santa Elena, Ecuador, under the name of *Pecten (Pecten) perulus* (286), the range of which is given as Panama to Lobitos, Peru. This Peruvian species was described as differing from *P. (O.) vogdesi* in its smaller size and thinner texture as well as "by its lower convexity of the right valve, its lower umbone which does not rise above the hinge margin and by its sulcated or mesially grooved ribs. The left valve differs by its wider, more flaring submargins and especially by its narrower ribs, and much wider interspaces, each carrying an intercalary riblet." Specimens of *P. perulus* in the collections of the California Academy of Sciences collected by Dr. Robert Hoffstetter (287) (who called attention to differences in the shell characters of this southern species and those of *P. vogdesi)* from Santa Elena, Ecuador, are purplish in color and smaller than *P. (O.) vogdesi*. The largest, a left valve, is 39.5 mm long. Other similar specimens were collected in Peru by Dr. Don L. Frizzell. The ribs on the right valves are shallowly sulcated near the ventral margin.

SUBGENUS *PATINOPECTEN* DALL

Patinopecten Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 695, April, 1898. "Type *P. caurinus* Gld." — Arnold, U. S. G. S., Prof. Paper 47, p. 48, 1906. "Type *P. caurinus* Gould." — Grau, Allan Hancock Pac. Exped., Vol. 23, p. 145, 1959. Type species *Pecten caurinus* Gould. — MacNeil, U. S. G. S., Prof. Paper 354-J, p. 225, 1961. "Type: *Pecten caurinus* Gould." — MacNeil, U. S. G. S., Prof. Paper 553, p. 40, 1967.

Type species (by original designation). — *Pecten caurinus* Gould [Proc. Boston Soc. Nat. Hist., Vol. 3, p. 345, December, 1850. "Hab. Port Townsend, Admiralty Inlet, Oregon." [Washington.] — Gould, U. S. Explor. Exped. (Wilkes), Vol. 12, p. 458, 1852; atlas pl. 42, figs. 569, 569a, 569b, 1856. Original locality cited. — Arnold, 1906, p. 101, pl. 38, figs. 1, 1a, 1b; pl. 39, figs. 1, 2. Pliocene to Recent. — Grau, 1959, p. 145, pl. 54, 1959. Range: Channel Inlet, Orca Inlet, Cordova, Alaska, to Point Reyes, California].

Range. —?Late Oligocene; early Miocene to Recent. Recent from central California to Japan. In about 18 to 91 meters (10 to 50 fathoms).

Description. — Shell large, nearly equilateral, rather flat, right valve slightly more convex than the left; ribs on the right valve flat and sometimes dichotomous, those on the left valve smaller and rounded; radial striae absent or inconspicuous; ears subequal, the right anterior one with a byssal notch; hinge nearly smooth, auricular denticles often present. (Adapted in part from Dall.)

Remarks. — Two specimens of a fossil *Pecten* from beds considered to be of middle Oligocene age in western Oregon were referred to *Patinopecten* by Schenck (288). These specimens are incomplete and poorly preserved and we are not certain whether or not they are referable to that taxonomic unit. MacNeil stated that the earliest American species of *Patinopecten* is known from beds of late Oligocene or early Miocene age in Alaska. This subgenus is represented in beds of middle Miocene age in Washington, Oregon, and California by *Pecten (Patinopecten) propatulus* Conrad and two varieties of that species have been described from central California. *Pecten caurinus* Gould and *P. oregonensis* Howe occur in beds of Pliocene age and the former also occurs in the Pleistocene and Recent. Several west American species formerly placed in *Patinopecten* were later referred to *Lituyapecten* MacNeil.

In Japan, Akiyama (289) referred 33 species to *Patinopecten* which he considered to be a genus ranging from late Oligocene to Recent, and he placed five others in a new subgenus *Masudapecten* (290). The latter was described as "allied to *Patinopecten* (s. str.), but can be distinguished from the right valve with less elevated radials and with conspicuous ctenolium and the left valve with less conspicuous threads."

Most of the Cenozoic pectens of Japan, formerly assigned to *Patinopecten*, were recently placed by Masuda (291) in four genera included in a new subfamily Fortipectininae. The species were distributed among *Masudapecten* Akiyama (type, *Masudapecten masudai* Akiyama), *Kotorapecten* Masuda (type, *Pecten kagamianus* Yokoyama), *Mizuhopecten* Masuda (type, *Pecten yessoensis* Jay) and *Nipponopecten* Masuda (type, *Pecten akihoensis* Matsumoto).

The taxonomic value of some of these genera may be open to question, but we withhold judgment of them because we have not studied large collections of Cenozoic

pectens from Japan.

Most workers have considered *Pecten yessoensis* Jay, the type of *Mizuhopecten* (Masuda, 1963, p. 151), to be closely allied to *Pecten caurinus* the type of *Patinopecten*. However, *Mizuhopecten* was differentiated from *Patinopecten* chiefly "by its having no auricular crurae with distal denticle, rounded, broad radial ribs and large auricles with wide and shallow byssal notch". A consideration of these shell characters led Masuda to place *Mizuhopecten* in the subfamily Fortipectininae.

Blanckenhornia von Teppner (292) has as type species *Pecten oweni* Arnold (not of De Gregorio, 1884), now known as *Pecten lohri* Hertlein, an early Pliocene species in California, with dichotomous ribs. This species and its descendant, *Pecten healeyi*, were apparently inhabitants of comparatively warm water. These two later Tertiary species with deeply medially sulcated ribs could be segregated under the separate subgenus *Blanckenhornia*. However, the degree of development of the medial sulcation of the ribs varies with species and may be of specific rather than of generic value. For this reason we have placed *Pecten healeyi*, which occurs in the San Diego Formation, in *Patinopecten*.

Jaworski (293) suggested a possible relationship of *Pecten oweni* Arnold (*P. lohri* Hertlein) with the early Jurassic *Pecten bodenbenderi* Behrendsen stock. Behrendsen's species is now assigned to the genus *Weyla* J. Böhm (type, *P. alatus* von Buch) and the suggested relationship with *P. lohri* is not evident from our research. The cardinal laminae on the hinge of *W. alata* are well developed and transversely grooved (see Jaworski, fig. 7).

Fortipecten Yabe and Hatai (294) includes a group of Pliocene species occurring in the north Pacific from Japan to Alaska. Typical forms of this group have thick shells and decidedly convex right valves with the beak overhanging that of the left valve.

Vertipecten Grant and Gale, was based upon *Pecten nevadanus* Conrad (*P. bowersi* Arnold), a Miocene species. This group of large chlamyds is quite distinct from *Patinopecten*, differing especially in that the left valve is more convex than the right one and is ornamented with large, rounded, scaly, irregular ribs of which every third or fourth usually is higher than the others.

Pecten (Patinopecten) healeyi Arnold
Plate 31, Figures 1, 4, 6, 7; Plate 33, Figure 9; Plate 36, Figures 8, 9; Text Figure 9

Pecten expansus Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 14, 1878. Later Tertiary of San Diego. — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. "well-digging in stratum B^2", San Diego; p. 29, "(stratum C)" "about ten miles northward from San Diego, on the seacoast of California". — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 87, 1889. Dall's record (1878) cited. — Cooper, Calif. State Min. Bur., Bull. No. 4, p. 31, 1894. "Pl. — San Diego." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 63, 1903. "Pacific Beach." Pliocene. — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 60, 1919. Dall's record (1878) cited.

Not *Pecten expansus* Smith, Quart. Jour. Geol. Soc. London, Vol. 3, pp. 413, 419, pl. 18, fig. 21, 1847.

Pecten (Patinopecten) expansus Dall, Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 706, pl. 26, fig. 1, April, 1898. "Pliocene of Pacific Beach (lower horizon), near San Diego, California." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 108, 1903. "Pliocene. — Pacific Beach, San Diego (Hemphill; Dall; Hamlin; Arnold)." — Schuchert, Dall, et al., U. S. Nat. Mus., Bull. 53, Pt. 1, p. 487, 1905. "Pliocene. Near San Diego, California."

Pecten (Patinopecten) healeyi Arnold, U. S. G. S., Prof. Paper 47, pp. 28 (as *Pecten healeyi*), 103, pl. 36, figs, 1, 1a; pl. 37, figs. 1, 1a, 2, 1906. "San Diego formation (Pliocene), Pacific Beach, San Diego County, Cal."; "Tiajuana, Mexico (A. W. Greeley)"; also "Purisima formation (lower Pliocene), near San Gregorio, San Mateo County, Cal." — Arnold, in Eldridge, U. S. G. S., Bull. 309, p. 240, pl. 34, fig. 1, 1907. Type. "San Diego formation (Pliocene), San Diego County." — Arnold and Anderson, U. S. G. S., Bull. 322, p. 154, pl. 26, figs. 1, 2, 1907. "San Diego formation (Pliocene), Pacific Beach, San Diego County, Cal." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 196, pl. 6, figs. 2a, 2b, 1931. Pacific Beach. "Middle Pliocene." Earlier records cited of Dall and others from San Diego. — Hanna and Hertlein, Calif. State Div. Mines, Bull. 118, Pt. 2, p. 176, fig. 3, 1941. "Pacific Beach, San Diego, California. San Diego formation, middle Pliocene." — Hertlein and Grant, Calif. Jour. Mines Geol., Rept. 35 State Mineral., p. 69, 1939. Gray sandstone overlying the basal conglomerate "about 1,200 feet south of the west end of Law Street." Pacific Beach, Pliocene. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 59, 1944. "bottom (60 feet) of David Smallcomb's well just north of the Mexican Boundary, in the bottom of Matadero Canyon, four-tenths of a mile west of the United States-Mexico Boundary monument No. 256," Pliocene. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 87, 1944. Earlier records cited. — Hertlein and Grant, Calif. State Divis. Mines, Bull. 170, Chap. 2, p. 60, 1954. "San Diego formation," Pliocene. — Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 46, pl. 21, figs. a, b, 1968. Pacific Beach, Pliocene.

P[ecten]. californicus Cossmann and Peyrot, Actes Soc. Linn. de Bordeaux, Tom. 68 (Conch. Néog. de l'Aquitaine, Tom. 2, Livre. 2 et Suppl.), p. 292, August 1, 1914. New name for *Pecten expansus* Dall, 1878. "fossile du Pliocène de Californie."

Not *Pecten californicus* Gabb, 1864. California, Cretaceous.

Pecten healeyi Arnold, McLaughlin and Waring, Map Folio accompanying Bull. 69, inside of back cover, species 42, pl. 1, fig. 42, 1914 (1915). "Etchegoin (San Diego) formation of Pacific Beach, San Diego Co., California." — J. P. Smith, Calif. State Min. Bureau, Bull. No. 72, p. 38, 1916. "San Diego and lower Fernando formations of the coastal region of southern California." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego." Pliocene. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, pp. 83, 84, 85, 1929. "San Diego Pliocene." — Hertlein and Grant, Calif. State Div., Mines, Calif. Journ. Min. Geol., Rept. 35 of State Mineral., pp. 69, 70, 71, 1939. Dall's record (1874) cited. Also "South slope of Soledad Mountain"; "David Small-

comb's well just north of the Mexican boundary and west of Tijuana, Mexico." — Hertlein and Grant, Mem.-San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, pp. 56, 57, 59, 1944. "India Street, particularly at the corner of Upas Street;" "thirty to forty feet above the base of the section" at Pacific Beach; also "south sloping spurs of Mount Soledad"; "near the Mexican Boundary about three-quarters of a mile from the sea," Pliocene. — Milow and Ennis, 57th Ann. Mtg. Cordilleran Sec. Geol. Soc. Amer., Field Trip Guidebook San Diego Co. — 1961, p. 28, 1961. "San Diego Formation."

Patinopecten healeyi Arnold, Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, 1941. "Strata at Pacific Beach," "San Diego," Pliocene. Also see Stewart, p. 92, "Pliocene at San Diego." — Woodring, U. S. G. S., Prof. Paper 222, p. 104, 1950. "Pacific Beach and inland," Pliocene. — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. "San Diego formation." Also Niguel Formation and others. — Masuda, Trans. Proc. Palaeont. Soc. Japan, New Ser., No. 52, pp. 147 (in text), 152, pl. 23, figs. 2a, 2b, 2c, 1963. "Loc. Rose Canyon, La Jolla Quadrl., San Diego, California, U. S. A. Pliocene." — Glibert and Van de Poel, Mém. Inst. Roy. Sci. Nat. Belgique, Deuxième Sér., Fasc. 78, p. 22, 1965 (as *Patinopecten* (s. s.) *healeyi*). Pacific Beach, San Diego, California, Pliocene.

Type specimen. — No. 148012, United States National Museum.

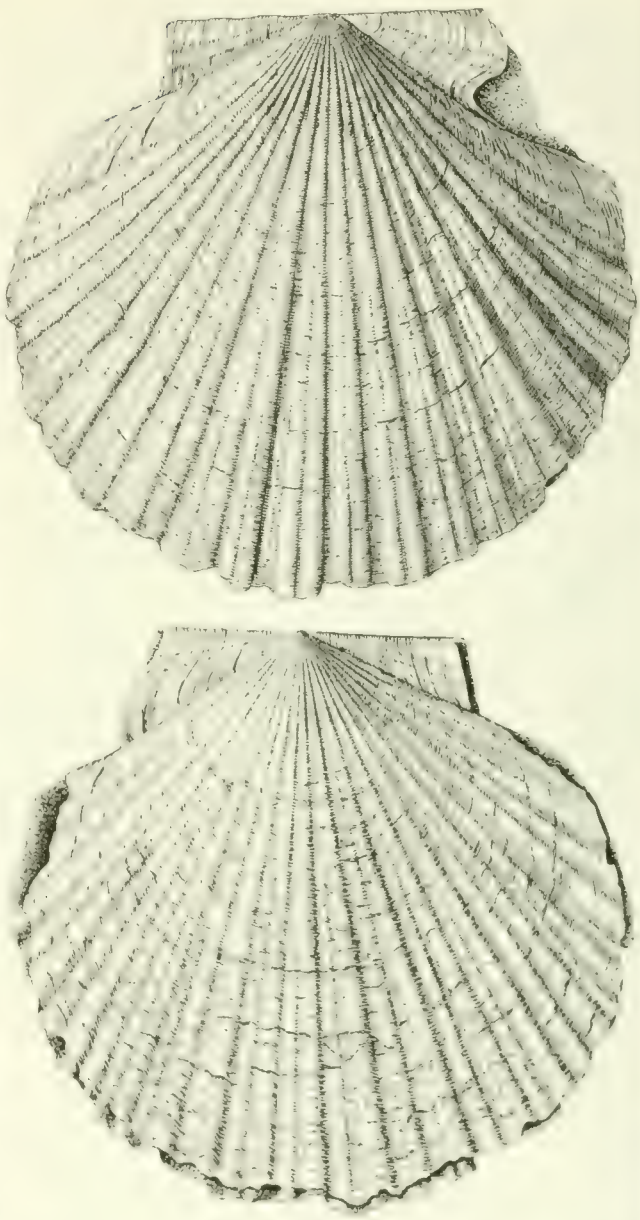
Type locality. — "San Diego formation (Pliocene), San Diego County, Cal."

Range. — Middle Pliocene, from Ferndale quad., California (Ogle), to Cedros Island and Bahía Tórtolo (Turtle Bay), Lower California, Mexico.

Occurrence in San Diego Fm. — C.A.S. 104, 105, 547, 957, 1130, 1135, 1138, 1177, 1178, 1179, 1181, 1182, 1183, 1186, 1199, 1399, 1400, 1401, 1404, 1413, 1414, 1418, 1419, 28158, 28453, 28454. L.A.M. 107, 122, 127, 305, 305A, 309, 318, 1132, A1323. S.D. 5, 10, 17, 21, 24, 27, 36, 37, 80, 88, 150, 331, 365, 402, 403, 404, 408, 417, 6304. U.C. A-8333. U.C.L.A. 294, 295, 298, 299, 300, 302, 309, 310, 312, 1384, 1385, 2359, 2420.

Original description. — Shell averaging about 130 millimeters in altitude, length about equal to height, inequivalve (the right slightly more ventricose than the left), equilateral, and with smooth margins; base evenly rounded; sides only slightly concave above. Right valve somewhat ventricose, and ornamented by 18 to 21 strong, squarish, sub-equal primary ribs, which become more or less dichotomous, and sometimes trichotomous, after 30 or 40 millimeters in length; medial sulcus of rib more or less deep, in some cases being as deep as the interspaces near the ends, thus completely dividing the primary rib; interspaces subequal, much narrower than the ribs, quite deeply channeled, and often ornamented by a small, rounded intercalary riblet; whole surface crossed by numerous fine lines of growth; hinge line less than one-half length of disk; anterior ear only slightly longer than left, arcuate in front, and ornamented by several obsolete radial ridges and numerous sharp incremental lines; byssal notch quite prominent; posterior ear slightly obliquely truncated, and ornamented by sharp incremental lines and sometimes by obsolete radiating ridges. Left valve much compressed; ribs narrow and rounded, more or less sharply toward the top (there being in some cases a narrow, slightly raised line along the top); interspaces wide, and each ornamented by a more or less prominent, rounded, intercalary riblet; whole surface striated concentrically by fine, sharp, wavy lines; ears obliquely truncated and sculptured similarly to those of the right valve. (Arnold.)

Dimensions. — Alt. 112 mm; long. 112 mm; hinge line, 50 mm; diameter 18 mm. (Arnold.)



Text Fig. 9. *Pecten (Patinopecten) healeyi* Arnold. Hypotype (Cat. No. 1950, University of California at Los Angeles), from Pacific Beach, San Diego; Pliocene. Length 130.8 mm. A. Right valve. B. Left valve. (Drawn by E. H. Quayle.)

Remarks. — This large, rather flat pecten is easily recognized by its flat-topped, medially sulcated radial ribs on the right valve and the rounded ribs with an intercalary in each interspace on the left valve. *Pecten healeyi* occurs at nearly every locality where fossils are found in the San Diego Formation in and near San Diego, California.

Juvenile specimens are smooth in the early stage but usually radial undulations of the anterior margin begin to form after the shell has attained a height of 3 to 5 mm. Occasionally specimens remain smooth up to a height of 23 mm. The ribs on the right valve, especially those toward the anterior and posterior margins, begin to develop a slight medical sulcus after the shell has attained a height of 10 mm, but such sulcations on the medial ribs are well developed only after a height of 30 to 40 mm has been attained. Occasionally the ribs on large specimens may bear two sulcations which thus divide the major ribs into three small riblets, but such forms, so far as known, have no taxonomic significance. One such right valve with a strong intercalary in each interspace from Pacific Beach in the collections of the San Diego Society of Natural History, is 165 mm high. The largest specimen of *Pecten healeyi* seen by us is one collected by G. P. Kanakoff from Loc. 107 (LAM), end of Arroyo Drive, San Diego, which is 222 mm long and 195 mm high. The hinge (incomplete) of a portion of a left valve in the same institution collected by Roy L. Moodie at Pacific Beach, is 99 mm long. The shell on lateral areas of the umbonal portion is 6 mm thick.

A low, narrow ridge is present on each side of the ligamental pit. The umbonal portion of the interior of many valves is covered with a layer of calcareous material, the weathered surface of which reveals a network of many fine, irregularly arranged plates or cells.

Pecten healeyi appears to be a descendent of *Pecten lohri* Hertlein (295) as mentioned by Arnold. He pointed out that some forms occurring in the Purisima Formation in San Mateo Co. (296), California, appear to be intermediate between *Pecten healeyi* and *Pecten lohri* in their respective lowest and highest stratigraphic ranges.

The stratigraphic ranges of these two species have been well defined by Woodring in the Santa Maria district, Santa Barbara Co., California. In that district *Pecten lohri* occurs questionably in diatomaceous strata of uncertain age and in the overlying Todos Santos Claystone and in the Tinaquaic Sandstone, the latter two of early Pliocene age. Overlying these are the Foxen Mudstone and Careaga Sandstone in which *Pecten healeyi* occurs. These are of approximately middle Pliocene age.

Compared to *Pecten healeyi*, the shell of *Pecten lohri* is smaller, more convex, has fewer (14 to 16) and coarser ribs on the right valve and it has a longer hinge line. The medial sulcations on the ribs begin nearer the dorsal margin than they do on *P. healeyi*, and the intercalary ribs are coarser.

Pecten healeyi and *P. lohri* are Pliocene members of a group which includes *Pecten propatulus* Conrad (297), described from mid-Miocene strata at Astoria, Oregon, and the only slightly different varieties described as *P. haywardensis* Lutz (298) and *P. haywardensis calaverasensis* Hall (299) from mid-Miocene strata in central California.

Pecten healeyi is quite distinct from *P. propatulus* and differs in the more numerous and more deeply sulcated ribs on the right valve, finer ribs on the left valve and smaller byssal fasciole beneath the right anterior ear. *Pecten oregonensis* Howe (300), described from Pliocene beds at Coos Bay, Oregon, is said to differ from *P. propatulus* in the higher ribs, wider umbonal angle, and in other details.

Pecten tryblium Yokoyama (301) from the late Miocene and Pliocene of Japan bears a resemblance to *P. healeyi* but is longer in proportion to the height, the ribs on the right valve appear to be proportionally narrower and the hinge line is longer.

Pecten yamasakii Yokoyama (302) was placed questionably in the synonymy of *Pecten healeyi* by Grant and Gale, and Kuroda (303) placed it as a subspecies of *P. healeyi*. The Japanese species is said to possess 19 to 22 tripartite ribs on the medial portion and bipartite ribs on the anterior and posterior portions of the right valve. A subspecies, *Pecten yamasakii ninohensis* Masuda (304) is another member of the Japanese group. These oriental forms differ sufficiently from the west American fossils to constitute distinct species. They were placed in the genus *Kotorapecten* by Masuda in 1963.

Pecten duplex Cooke (305) described from beds of mid-Tertiary age on the island of Antigua in the Caribbean Sea, was compared by its author with *Pecten healeyi*. The Caribbean form has medially sulcated ribs on the right valve but it is said to be smaller and the ribs on the left valve are square-topped and bear a shallow medial groove. This latter feature is reminiscent of *Pecten yakatagensis* Clark (306) which was described from strata of Pliocene age in southeastern Alaska but the two are not closely related. Olsson and Richards assigned the Antiguan fossil to *Flabellipecten*. The form illustrated by Manning and Ogle under the name of "*Pecten oregonensis* Howe var." (307) from Boulder Creek near Ferndale, California, also has square-topped medially grooved ribs on the left valve. It was described later by MacNeil as *Patinopecten (Lituyapecten) falorensis* (308).

Pecten healeyi is an index fossil of the San Diego horizon, middle Pliocene, of California and northern Lower California. It has been reported from many localities from Ferndale, northern California, to Cedros Island and Bahía Tórtolo (Turtle Bay), Lower California, Mexico. Also from Santa Cruz Island, California.

This species lived in warm water unlike its northern relative *Pecten caurinus* Gould which followed it in stratigraphically later Pliocene and Pleistocene beds in California.

[*Pecten (?Patinopecten) merriami* Arnold]

Pecten (Pecten) merriami Arnold, U. S. G. S., Prof. Paper 47, p. 99, pl. 30, figs. 1, 1a, 2, 1906.

P[ecten]. merriami Arnold, J. P. Smith, Calif. State Min. Bureau, Bull. No. 72, p. 38, 1916. "San Diego and lower Fernando formations of the coastal region of southern California." Pliocene.

Type specimen. — Number 12086, University of California, Museum of Paleontology.

Type locality. — "from light-colored shale underlying the conglomerate on San Felician Creek, near Piru, Ventura County," California. "Pliocene (lower)."

Range. — Probably middle or late Pliocene.

Remarks. — The only record of occurrence of *Pecten merriami* in the San Diego Formation is the equivocal one

of J. P. Smith. We have not seen any specimens from the Pliocene beds at San Diego which could be referred to this species.

We have examined a cast of the holotype, No. 6100 (Calif. Acad. Sci. Dept. Geol. Type Coll.), and we can add but little to Arnold's discussion of this species. The hinge on the type specimen is lacking as is the shell on most of the umbonal area. A few ribs on the lateral areas are slightly but definitely medially sulcated. The taxonomic status of this species is uncertain.

SUBGENUS *LITUYAPECTEN* MACNEIL

Lituyapecten MacNeil, U. S. G. S., Prof. Paper 354-J, p. 227, 1961.

Type species (by original designation). — *Patinopecten (Lituyapecten) lituyaensis* MacNeil [1961, p. 231, pl. 39, figs. 1, 3; pl. 40, figs. 1-5; pl. 41, fig. 1; pl. 42, figs. 1, 2, 4; pl. 43, figs. 1-4. "Type locality. — Upper mudstone unit of unnamed upper Tertiary formation, about 300 to 340 feet above the base of the upper mudstone unit, southwest of Cenotaph Island, Lituya Bay, Alaska, USGS M270". Pliocene].

Range. — Late Oligocene (Poul Creek Formation) or early Miocene, to middle Pliocene, Alaska; Pliocene of Washington, Oregon, California, and northern Lower California, Mexico.

Description. — "The new subgeneric name, *Lituyapecten*, is here proposed to include the species of *Patinopecten* having one to several rows of frill-like flanges on the ribs of the left valve" (MacNeil, 1961, p. 228).

Remarks. — This group of scallops is generally referred to *Patinopecten* in earlier works. In support of possible relationship with *Patinopecten*, MacNeil reported the presence of small frill-like flanges close to the beak the ribs of some left valves of *Pecten (Patinopecten) propatulus*. The same author pointed out the difficulty of identification based only on right valves which may be similar in some members of *Lituyapecten* though the left valves may be quite dissimilar.

The ribs on the left valves of several species in this group are high, narrow and flat-topped, those on the right valve, flat-topped or rounded and often undercut on the sides. In addition to the frill-like flanges on the ribs, concentric microsculpture is present on the valves. MacNeil mentioned that the fine imbricating microstructure present on many specimens of *Patinopecten* and *Swiftopecten* was not observed by him on any specimens of *Lituyapecten*.

Seven species from the medial Tertiary of western North America were assigned to *Lituyapecten* by MacNeil. One of these is present in the San Diego Formation.

Pecten (Lituyapecten) dilleri Dall
Plate 35, Figures 4, 7

Pecten (Lyropecten) dilleri Dall, Nautilus, Vol. 14, No. 10, p. 117, February, 1901.

Pecten (Patinopecten) dilleri Dall, Arnold, U. S. G. S., Prof. Paper 47, p. 62, pl. 5, fig. 2, 1906. Rio Dell, Eel River, Humboldt Co., California. "Upper Miocene or lower Pliocene". — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 431, pl. 30, fig. 1, 1926. Near Elephant Mesa, Lower California, Pliocene. Also earlier records.

Patinopecten dilleri Dall, Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, pp. 65, 83, 84, 106, 107, pl. 11, figs. 1, 9, 1950. Santa Maria district, California, Pliocene. Also p. 104, "India and Upas streets, San Diego." — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. "San Diego formation." Also Niguel Formation and others.

Type specimen. — "Cotype" No. 164846, United States National Museum. (Arnold.)

Type locality. — "horizon of Rio Dell on the Eel River, California." (Dall.) According to Keen and Bentson (Geol. Soc. Amer., Spec. Papers No. 56, p. 85, 1944), syntypes of this species are from the "[W 1/2 5, T 1N, R 1E, H], Humboldt Co." A study of the strata in the area from which the type of *Pecten dilleri* came led Ogle (309) to the opinion that "it suggests that the type must have been found in the lower part of the Rio Dell formation."

Range. — Middle Pliocene, California, and northern Lower California, Mexico. "cf." Lituya Bay, Alaska, late Tertiary (MacNeil, 1961).

Occurrence in San Diego Fm. — U.C.L.A. 307.

Original description. — Shell large, rather compressed, nearly orbicular with a relatively short, straight hinge-line, dorsally rectangular, nearly smooth, subequal ears, the posterior with three small riblets; a well marked though shallow byssal fold; and moderately thick valves. The right valve is somewhat more convex and strongly sculptured, bearing 29-30 high, narrow, T-rail-shaped ribs, flattened above, overhanging narrower, deep, nearly smooth channels; and with marked concentric imbrication, feeble on top of the ribs but articularly scaly at their sides. The sculpture of the left valve is less pronounced, hidden in the matrix, but apparently similar. Alt. 192, lat. 175, diam. about 35 mm. The lateral edges are slightly defective, the submargins very narrow. (Dall.)

Remarks. — One well preserved specimen found in the San Diego Formation is present in the collections of the University of California at Los Angeles. The record of *Pecten dilleri* from San Diego by Woodring was based upon this specimen. It is 88.6 mm long, 88.6 mm high (anterior margin slightly defective), convexity (both valves together), 17 mm. There are 27 radial ribs of which two nearest the anterior margin on the right valve are medially grooved. The riblets on the anterior ears are fine but well defined, those on the posterior ears only faintly indicated. Scaly concentric lamellae are only faintly noticeable on the right valve but on the left valve these are well developed. A portion of a right valve, 61 mm long, is present in the collection from Loc. 307 (UCLA).

On some specimens of this species from other formations, concentric lamellae may cross the ribs or only flanges may be present along the margins of the ribs on the right valve. On well preserved left valves, strong, elevated, concentric lamellae cross the ribs, or are occasionally interrupted and alternating, as shown on the illustrations of a left valve from northern Lower California by E. K. Jordan and Hertlein (1926, pl. 30, fig. 1).

A study of the species of *Lituyapecten* led MacNeil (1961, pp. 233, 235) to conclude that *P. (L.) dilleri* probably stems from *P. (L.) poulcreekensis* MacNeil (310), which was described from the upper portion of the Poul Creek Formation in Alaska of early Miocene age. He

discussed and illustrated specimens (see MacNeil, 1961, p. 235, pl. 41, figs. 4, 5; pl. 45, fig. 1) under the name of "*Patinopecten (Lituyapecten)* cf *P. (L.) dilleri* (Dall)," "from the upper mudstone unit of an unnamed Tertiary formation, Lituya district, Alaska, USGS 7931," of Pliocene age.

Akiyama suggested possible relationship between *P. (L.) dilleri* and *P. kurosawaensis* Yokoyama (311) which was described from beds of late Pliocene age in Japan. That species is said to bear 36 to 40 round-topped ribs. No mention is made in the description of any frill-like flanges on the ribs, a shell character well developed on *P. (L.) dilleri.* Evidence of close relationship between the Japanese species and *P. (L.) dilleri* needs confirmation.

Pecten (Lituyapecten) purisimaensis Arnold (312), another member of the *P. (L.) poulcreekensis* group, is characterized by fewer (22 to 24), usually broader ribs on the right valve and narrower, sharper ribs with correspondingly wider interspaces on the left valve.

Fossils cited as "*P. dilleri variety*" by Woodring (1950, pl. 9, figs. 6-8), from the Sisquoc Formation in the Santa Maria district are characterized by the presence of riblets in the interspaces on the left valve and by minute riblets crossed by very fine lamellae in the interspaces on the right valve.

Pecten dilleri Dall was recorded by Arnold and Hannibal (313) as occurring in strata of Pliocene age in western Washington but Weaver (1943) later cited *P. coosensis* from beds of that age in both western Washington and Oregon.

Pecten (Lituyapecten) coosensis Shumard (314), bears a resemblance to *P. (L.) dilleri* in the slightly developed flanges on the ribs and in that the ribs bear one or more medial grooves toward the ventral margin, a feature well shown in the illustrations by Weaver and by Trumbull. Also a fold is present on the anterior ear of the left valve. MacNeil (1961, p. 233) suggested that *P. (L.) coosensis* is a member of the *P. (L.) yakatagensis* group.

Akiyama suggested that *P. (L.) coosensis* is closely allied with *P. nakatombetsuensis* (315) a species said to be sculptured with 29 elevated, flat-topped, squarish ribs on the right valve and 24 round topped ribs on the left valve, from the early Pliocene of Japan. Judging from the description and illustrations only, the Japanese species is quite distinct from *P. (L.) coosensis.*

Pecten dilleri has been recorded from California in Humboldt Co., Santa Barbara Co., and San Diego Co., and in Lower California northwest of Elephant Mesa. So far as known, typical specimens of this species occur only in beds of approximately middle Pliocene age.

GENUS *CHLAMYS* RÖDING IN BOLTEN

Chlamys Röding in Bolten, Mus. Boltenianum, Pt. 2, p. 161, 1798. Numerous species cited, the first two are, "*C. Cinnabarina.* Dei zinoberrothe Mantel. Gmel. *Ostrea islandica.* sp. 55. Chemn. 7.t.65. fig. 615, 616. 9 St." and "*C. islandica.* Der isländische Mantel. eod. 4 St." — Meek, Rept. U. S. Geol. Surv. Terr., Vol. 9, p. 23, 1876. "*P. Islandica,* Linn . . . . this shell was Bolten's first species of *Chlamys* . . . . it has been cited by Herrmannsen and others as its type." — Woodring, Carnegie Inst. Washington, Publ. 366, p. 64, 1925. "Type (by subsequent designation, Dall, 1898). — *Pecten islandicus* Müller." — Arkell, Palaeontogr. Soc. (London), Vol. 82, for 1928, Brit. Corall. Lamellibr., Pt. 2, p. 102, issued December, 1930. [No type cited.] — Cox, Mem. Geol. Surv. India, Palaeo. Indica, Ser. 9, Vol. 3, Pt. 4, p. 3, 1952. "Genotype. — *Pecten islandicus* Müller (1776, p. 248), Recent circumboreal; designated by A. N. Herrmannsen, 1846."

Not *Chlamys* Koch, 1801. Coleoptera. Renamed *Arthrochlamys* by von Ihering, Rev. Mus. Paulista, Vol. 6, p. 642, 1905.

Myochlamys von Ihering, An. Mus. Nac. Buenos Aires, Vol. 14 (Ser. 3[a], Vol. 7), p. 251, 1907. "Maintenant cependant ayant verifié que les noms de Bolten ne peuvent pas être admis, je ne peux pas trouver un autre nom generique pour *Chlamys* auct., et je propose par cette raison le nom générique de *Myochlamys* n. n., pour substituer *Chlamys* Bolten."

Chlamydina Cossmann, Rev. Crit. de Paleozool., Vol. 13, Livr. 1, p. 67, January, 1909. New Name for *Myochlamys* von Ihering, 1907, not *Myochlamys* Fairman, 1876. Coleoptera.

Type species (by subsequent designation, Herrmannsen, Indic. Gener. Malacozoor., Vol. 1, p. 231, 1846). — "Typus: *Pecten Islandicus* Linn." [Müller, Zool. Danicae Prod., p. 248, 1776. "I. Hörpudiskur. Isl. R. 901. t. 10.f.5. edulis." Illustrated by Chemnitz, Syst. Conchyl.-Cab., Bd. 7, p. 314, pl. 65, figs. 615, 616, 1784. — Arnold, U. S. G. S., Prof. Paper No. 47, p. 113, pl. 45, figs. 1, 1a, 1906. These figures reproduced by I. S. Oldroyd, "The Marine Shells of the West Coast of North America," Stanford Univ. Publ. Univ. Series Geol. Sci., Vol. 1, pl. 8, figs. 1, 2, 1924, and by Korobkov, Metodicheskoe Rukovodstvo Po Tretichnym Molluskam. Plastinchatozhabernye [Lamellibranchiata], Gostoptehizdat [Publishing house], Leningrad, pl. 63, figs. 1a, 1b, 1954. See also discussion of this species by Jensen, Danish Ingolf-Exped., Vol. 2, Pt. 5, p. 15, pl. 1, figs. 4a-d, 1912. Greenland, Iceland, and the Faroes; and MacNeil, U. S. G. S., Prof. Paper 553, pp. 33-34, pl. 18, fig. 8; pl. 19, figs. 2, 5; pl. 24, figs. 12, 13, 1967.]

Range. — Early Triassic to Recent, worldwide. Recent from low tide to about 2013 meters (1100 fathoms).

Description. — Shell suborbicular to subtrigonal and higher than long, frequently slightly oblique, equivalve or one valve slightly more convex. Auricles clearly delimited from the body of the shell, unequal, the anterior ones longer than the posterior. Byssal sinus present beneath the anterior auricle; ctenolium usually developed. Cardinal crura variable in number and strength; auricular crura sometimes present, but seldom prominent. Ornamentation similar or dissimilar on the two valves, normally consisting of radial threads or ribs and thin, concentric lamellae which often form rough, scale-like projections, especially on the left valve; ornamentation on some species is almost obsolete or lacking; margin usually scalloped. (Adapted from Arkell, 1930, and Cox, 1952.)

Remarks. — *Chlamys,* on the basis of shell characters, is here used as a genus name. It is recognized, however, that on the basis of similarity of anatomy, *Chlamys* could be retained as a subgenus (316) of *Pecten.*

The genus *Chlamys,* in a broad sense, includes the majority of known species of Pectinidae. These species all possess a well developed byssal sinus but the ornamen-

tation varies from fine to coarse ribs or to mere undulations of the shell to nearly smooth unsculptured valves. Valves of some species of *Chlamys* which are nearly smooth usually retain at least some ribbing on the auricles. Some species attach themselves by a byssus to some object and move about comparatively little. Others break the attached threads and swim about freely. Some large forms lie upon the sea-bottom and in the adult stage, apparently move about but little if any. Many of the Recent species are brilliantly colored.

There is great variation in the ribbing of the *Chlamys* group as shown by Fedotov's (317) study of Recent and fossil forms of *Chlamys islandica.*

SUBGENUS *CHLAMYS S. S.*

Range. — Early Triassic to Recent.

Description. — Shell usually with the dorsal margins of the body steeply sloping and the height greater than the length; not strongly inflated. Byssal notch deep, ctenolium well developed. Ornamentation similar or slightly dissimilar in the two valves, consisting of close-set radial threads or narrow ribs, which are frequently squamose. About two pairs of not very prominent cardinal crura are present. (Cox, 1952.)

Remarks. — Ribbing on the two valves in this group is usually dissimilar, those on the right valve usually increase by dichotomization, those on the left valve by intercalation. The two valves are gently convex, sometimes the left one more so than the right one. Arkell called attention to the fact that the "internal ribs near the margin are rounded, grooved and not very prominent."

As pointed out by others, the fine, spiny ribbed forms resemble, in many features, the late Paleozoic Aviculopectinidae. They are well represented both as fossils and Recent in western North America.

Some of the characters of the shell of *Chlamys s. s.* which differ from those of the subgenus *Aequipecten* Fischer are the greater height than length, smaller apical angle, more numerous often bifurcating radial ribs and the unequal auricles. Arkell (1930, p. 102) mentioned that in *Aequipecten* "the ribs are usually fewer and far more regular, not bifurcating, while the internal ribs near the margin are prominent, flattened and marginally pointed." Furthermore, the inner surface of the valves of *Chlamys*, except near the margin, is rippled, whereas that of *Aequipecten* has clearly defined ribs.

It is difficult, however, to determine whether some species should be assigned to the subgenus *Chlamys s. s.* or to *Aequipecten.* Staesche (1926, p. 26) believed that various groups of species referable to *Aequipecten* arose independently from time to time from *Chlamys.* He (318) assigned 25 forms from the Schwabian Jurassic to *Chlamys* and eight to *Aequipecten.* From the Jurassic of France, Dechaseaux (319) assigned 25 forms to *Chlamys* and 32 to *Aequipecten.* Some of these are now placed in different subgenera.

From a study of Recent species Dechaseaux (1936, p. 126) inferred that the presence of *Chlamys* in a fauna indicated proximity to a rocky bottom.

Chlamys (Chlamys) hastata Sowerby
Plate 33, Figures 4, 5, 6

P[ecten]. hastatus Sowerby, Thes. Conch., Vol. 1, p. 72, pl. 20, fig. 236, 1842. — Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "Pliocene." "well at San Diego." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. "Well-digging in stratum B^2," San Diego. — Cooper, Calif. State Min. Bur. Seventh Ann. Rept. State Mineral, p. 257, 1888."Pl. — San Diego well." — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, August, 1898. Dall's record (1874) cited. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 63, 1903. "Pacific Beach," Pliocene. — Arnold., U. S. G. S., Prof. Paper 47, p. 28, 1906. "San Diego formation" at "Pacific Beach." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 173, 182, 1912. "San Diego-Purisima." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 151, 1919. "San Diego," Pliocene. — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited. — Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 53, pl. 29, figs. 1, 3, 1924. "Range. Monterey to San Pedro, California."

Pecten (Chlamys) hastatus Sowerby, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 109, pl. 11, figs. 4, 4a ("Pliocene, Deadman Island"), 1903. "Pliocene . . . San Diego

Key to Species and Subspecies of *Chlamys* s. s.

A. Interspace with minute radial or oblique groovings

- a. Interspaces with fine radial grooves; ribs even, fine, low . . . . *opuntia*
- aa. Interspaces with minute oblique groovings; major ribs consisting of a fascicule of three riblets
  - b. Each fascicule with central riblet higher and with very long spines . . . . . *hastata*
  - bb. Each fascicule with three riblets of nearly equal height with spines of moderate height . . . . . *hericius*

B. Interspaces with minute reticulate, honeycomb-like sculpture

- a. Major ribs on right valve composed of 3 fascicules of nearly equal riblets . . . . . *ellisi*
- aa. Major ribs on right valve simple, flattened on top
  - b. Ribs on left valve simple, not fasciculated or imbricated; ribs with honeycomb-like sculpture . . . . . *jordani*
  - bb. Ribs on left valve often fasciculated and imbricated; top of ribs usually lacking honeycomb-like sculpture . . . . . *rubida*

(Arnold)". — Arnold, U. S. G. S., Prof. Paper 47, p. 108, pl. 41, fig. 4 ("Pliocene, San Raphael Hills, Santa Barbara County, Cal."); pl. 42, figs. 1, 1a, 2, 2a (Recent Monterey Bay, California, 1906. "Pliocene . . . Pacific Beach, San Diego (Arnold," — Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, table opp. p. 78, 1929. "San Diego Pliocene."

Pecten (Pecten) hastatus Sowerby, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 166, pl. 11, figs. 6a, 6b, 1931. Page 167. "San Diego (Dall, 1874)", "Pliocene."

Chlamys hastata Sowerby, Grau, Allan Hancock Pac. Exped., Vol. 23, p. 84, pls. 27, 28. 1959. Monterey to San Diego, California, Recent. Also Pliocene and Pleistocene.

Mimachlamys hastata Sowerby, Glibert and Van de Poel, Inst. Roy. Sci. Nat. Belgique, Mém., Deuxième Sér., Fasc. 78, p. 31, 1965. Spanish Bight (North Island), California; Pleistocene.

Type specimen. — "The only specimen we have seen is in the collection of the Rev. F. J. Stainforth." (Sowerby.) Location of type specimen unknown to the present authors.

Type locality. — No locality originally cited. Subsequently designated by Grau (1959, p. 85) as "San Diego, California."

Range. — Late Miocene (Nomland; Stanton (cf.); Addicott and Vedder); Pliocene to Recent. Recent from Monterey to San Diego, California, in 18 to 91 meters (10 to 50 fathoms).

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 105, 1132, 1400, 2028, 28892. L.A.M. 107, 122, 305. S.D. 34, 2915. U.C.L.A. 294, 2420.

Original description. — T. ovali subtrigonâ, subelongatâ, scabrâ; auriculis inaequalibus, posticis minimis, anticis magnis, scabroso-sulcatis: valvâ sinistrâ, costis 8, inaequalibus, valdè elevatis, angulatis; spinas numerosas, erectas, subcrispatas ferentibus. Costis interstitialibus numerosis, inaequalibus, serratis: valvâ dextrâ, costis 22, angulatis, spinosis; colore rubro, intus albo. Long. 0.95; lat. 0.30; alt. 1.15; poll. (Sowerby.)

Oval, inclining to triangular, rather elongated, rough; with very unequal ears, the posterior ones being very small; the upper valve has eight unequal, elevated, angular ribs, with numerous erect, slightly curved sharp spines, and several smaller spinose ribs in the interstices. The lower valve has 22 more nearly equal ribs with more numerous and smaller spines on the angles. (Sowerby.)

Remarks. — This spiny scallop occurs in strata of Pliocene age at Pacific Beach as well as on the San Diego mesa. The largest specimen from that area which we have seen is a right valve from Loc. 2028 (CAS), Pacific Beach. It is 43.2 mm long and 48.5 mm high. Some of these specimens retain details of sculpture typical of *Chlamys hastata* with the prominent central riblet bearing long, projecting spines.

Eroded specimens of this species are often difficult to separate from similar specimens of the subspecies *C. hastata hericius*. In general, the major ribs on *C. hastata* are rather sharply defined whereas on *C. h. hericius* these are composed of a fascicule of riblets the whole with a convex outline. The right valve of *C. hastata* is sculptured with 9 or 10 paired, high, steeply sloping ribs, each bearing a row of long spines. There are 1 to 3 thread-like spiny riblets in the interspaces. Very fine, incised groovings are present on the surface in the interspaces between the ribs. On the right valve of *C. h. hericius*, a generally more northern, larger form, there are three riblets of nearly equal size (although the central one is slightly larger) on each major rib which lend a rounded appearance to the ribs. The ribs on the left valve of *C. hastata*, 9 or 10 in number, are narrower and more steeply sloping than are those of *C. h. hericius*.

A large Recent specimen of *Chlamys hastata* in the collections of the California Academy of Sciences is 60 mm long, 63.5 mm high (dorsal-ventral), the convexity (both valves together), about 16.5 mm. The shells of this species are beautifully tinted with pink or pinkish-white or orange coloration. This scallop can either swim about or may remain attached.

The species described as *Pecten (Chlamys) lawsoni* (320) by Arnold was based upon a poorly preserved specimen from "the Pliocene at the Waldorf asphalt mine, 4 miles south of Guadaloupe, Santa Barbara County", is generally relegated to the synonymy of *C. (C.) hastata*.

Adegoke (321) recently mentioned that most of the records of occurrences of *C. hastata* from the Santa Margarita Formation, of late Miocene age, are probably referable to species of *Hinnites*.

The fossil described under the name of *Pecten (Chlamys) hastatus* var. *ingeniosa* Yokoyama (322) from late Tertiary beds in Japan is a species distinct from the west American shell. Likewise, the form indicated by Slodkewitsch (323) as a questionable variety of *C. hastata* from the upper horizon of the Kavran series of Pliocene age in Kamtschatka is apparently not referable to Sowerby's species. Vaillant's record of *Pecten hastatus* from Suez later was referred by Lamy (324) to *Chlamys squamosa decoriata* Jousseaume.

The species described as *Pecten denticulatus* by Adams and Reeve (325), with the locality "Hab. Shores of Borneo," was believed by Bavay (326) to be a juvenile form of *Chlamys hastata* and Grau (1959 , pp. 86-87) accepted this view. This assignment may be correct, especially when considering the fact that some other species described by Adams and Reeve as coming from the East Indian region are now known to be west American species. Cox (327), however, considered Bavay's assignment of *Pecten denticulatus* Adams and Reeve to *Chlamys hastata* to be very improbable and proposed a substitute name for the former, *Chlamys odontata*, because of a prior *Pecten denticulatus* von Hagenow, 1842.

MacNeil (1967, pp. 14-15) recently discussed the *Chlamys (Chlamys) hastata* group.

Chlamys (Chlamys) hastata hericius Gould
Plate 33, Figure 2

Pecten hericius Gould, Proc. Boston Soc. Nat. Hist., Vol. 3, p. 345, December 1850. — Gould, U. S. Explor. Exped. (Wilkes), Vol. 12, p. 457, 1852. Atlas, Moll., pl. 42, figs. 570, 570a, 570b, 570c, 1856. "Inhabits the Straits of De Fuca Oregon." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 63, 1903. "Pacific Beach", "Pliocene". — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 52, pl. 7, figs. 1, 2, 1924. (Copy of illustrations from Arnold, 1906, pl. 43, figs. 3, 3a). "Range. Port Althorp, Alaska, to San Diego,

California."

Pecten hericeus Gould, Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 29, 1878. "San Diego," "Later Tertiary." Page 29, "about ten miles northward from San Diego, on the seacoast", "(Stratum C)."

Pecten hastatus Sowerby, Cooper, Calif. State Bur. Min., Seventh Ann. Rept. State Mineral., p. 257, 1888, (in part, according to Arnold, 1906). "San Diego well," Pliocene. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 166, 1931 (in part, *Pecten hericeus* in synon.).

Pecten (Chlamys) hericeus Gould, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 110, pl. 11, fig. 2 ("Pliocene, Deadman Island"), 1903. "San Diego well (Cooper): San Diego (Arnold)." — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 16, pl. 23, figs. 1, 2, 1924. (Copy of Illustrations by Arnold, 1906, pl. 43, figs. 3, 3a). Port Althorp, Alaska, to San Diego, California. — Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, table opp. p. 78, 1929. "San Diego Pliocene."

Pecten (Chlamys) hastatus Sowerby var. *hericius* Gould, Arnold, U. S. Geol. Surv., Prof. Paper 47, p. 110, pl. 43, figs. 3, 3a (Recent, Puget Sound), 1906. "Pacific Beach, San Diego (Hemphill, Arnold)", "Pliocene."

Chlamys hastata hericia Gould, Grau, Allan Hancock Pac. Exped., Vol. 23, p. 87, pl. 29, 1959. Gulf of Alaska to Santa Barbara, California, Recent. Also Pliocene and Pleistocene.

Chlamys ("Chlamys") hastata hericius (Gould), MacNeil, U. S. Geol. Surv., Prof. Paper 553, p. 14, pl. 21, figs. 1, 3, 1967. Puget Sound, Recent.

Type specimen. — No. 5955, United States National Museum.

Type locality. — "Hab. Straits of De Fuca, Oregon."

Range. — Late Miocene (Arnold); Pliocene to Recent. Recent from Port Althorp, Alaska, to Santa Barbara, California, from minus tide to 146 meters (80 fathoms).

Occurrence in San Diego Fm. — C.A.S. 2028.

Original description. — T. rotundato-triangularis, equilateralis, equivalvis; valvis convexis, sub-tumidus: valva superior rosea, lineis exilibus concentricis exasperata, et costis ad 24 angulatis, alternis majoribus et spinis erectis fornicatis insculpta: valva inferior pallidior colore saturatiori zonata, costis sub-equalibus spiniferis armata; natibus acutis, prominentibus; auribus obliquis valdè inequalibus radiatim squamoso-striatis; intus porcellana; marginibus crenulatis, rosaceis. Long. 4 1/2; alt. 1 1/4; lat. 4 3/4 poll. (Gould.)

Remarks.—This subspecies is found only occasionally in Pliocene strata at San Diego. This paucity was noticed by Arnold and it is true of the collections which we have seen from that area.

One excellent right valve collected by F. M. Anderson at Loc. 2028 (CAS), Pacific Beach, along with typical *C. hastata*, is 53.6 mm long, and 58 mm high. This bears out Arnold's observation that fossil forms of this subspecies are generally smaller than Recent specimens. A huge Recent specimen taken by Walter Eyerdam in the Straits of Juan de Fuca, Puget Sound, Washington, was reported to be 93 mm high and 73 mm wide (see Min. Conch. Club South. Calif., No. 190, p. 18, 1959).

Chlamys hastata hericius (328) differs from typical *C. hastata* in the generally larger size, less spinose ribs and in that the ribs of the right valve are composed of a fascicule consisting of three nearly equal, spiny riblets, the middle one slightly more prominent, the whole more convex in outline than the corresponding fascicule on *C. hastata*. There is usually a riblet in the middle of each interspace and between this and the major fascicule there are usually two smaller threads and occasionally also a finer pair of intercalaries. The ribs on the left valve also consist of a fascicule of riblets which is more convex than that of *C. hastata*. The surface in the interspaces between the ribs of *C. h. hericius* is usually sculptured with very fine oblique grooves or scratches similar to those on *C. hastata*. Grau pointed out that the shell of *C. hastata* often is oblique, whereas that of *C. h. hericius* seldom is.

Chlamys hastata hericius is a generally more northern form, at the present time occurring abundantly in Puget Sound often embedded in sponges. It has been recorded as occurring from Port Althorp, Alaska, south to Newport Bay, California, but we have not seen specimens from southern California.

The form originally described as *Pecten islandicus pugetensis* I. S. Oldroyd is similar to *C. h. hericius* but it is generally smaller, the interspaces and sometimes the entire valve bears fine honeycomb-like sculpture.

Masuda suggested that *Chlamys miyatokoensis* Nomura and Hatai (329), which occurs in beds of early Miocene age in Japan, may be an ancestral form of *C. hastata hericius*. The riblets forming the major ribs of the Japanese form are said to be divided into three subequal parts by radial grooves and there are but two or three riblets in the interspaces. Judging from the illustrations given by Masuda, the radial fasciculi appear to be less elevated into raised ribs lending an appearance of nearly equal, spiny, radial riblets over all the right valve. The anterior ears also are smaller than those on the west American form. The medial sulcation giving rise to the paired character of the ribs mentioned by Masuda also is noticeable on some west American specimens (see our plate 33, figure 2). Some of the illustrations given by Masuda bear a decided resemblance to some forms of *C. h. hericius* (see especially his plate 35, figure 9a) and his suggestion that *C. miyatokoensis* may be an ancestral form of *C. h. hericius* is plausible. The two, however, are apparently distinct forms.

Masuda (330) also mentioned similarities and differences between *Chlamys hastata hericius* and the Japanese species *C. kaneharai* Yokoyama (331). The similarities are very much less pronounced than are those with *C. miyatokoensis*.

Chlamys (Chlamys) hastata ellisi n. subsp.
Plate 31, Figures 2, 3; Plate 34, Figure 6

Description. — Shell characters similar to those of *Chlamys hastata* but differing in the presence of fine honeycomb-like tesselations covering the interspaces and sides of the ribs, but obscured on the tops of the ribs where covered by strong imbricating spinose sculpture. Length, 66 mm; height, 68.5 mm.

Type specimen. — Holotype, a right valve, Invertebrate Paleontology Collection, Los Angeles County Museum.

Type locality. — Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8,

T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U. S. G. S. topog. map, San Ysidro quad., ed. 1943).

Range. — Known with certainty only from strata of middle Pliocene age at the type locality.

Remarks. — In addition to the holotype a right valve, 31 mm high, and two small left valves, the larger one 20.8 mm high are referable to this new subspecies. The entire surface of left valves is covered with minute tesselations. This sculpture, composed of a layer of minute scaly imbrications, is usually preserved in the interspaces but sometimes covers the ribs as well. Often the scaly honeycomb-like material is mostly gone and the interspaces retain only a pattern of minute reticulation. This type of sculpture ("Gittersculptur" of Philippi (332) is present on *C. islandica* and allied forms. It also occurs on many species in other groups of scallops, including *Manupecten, Patinopecten and Swiftopecten.* It may be a primitive character. This minute sculpture may easily disappear with erosion and it is quite possible that some fossil specimens lacking perfect preservation in the present as well as in other collections, and referred to *Chlamys hastata* or *C. h. hericius,* may represent *C. h. ellisi* n. subsp. The only reliable basis for separating the present new subspecies form *C. hastata* rests entirely on the presence and recognition of the surficial tesselated sculpture.

The minute sculpture of the present subspecies is similar to that of the form described as *Pecten islandicus pugetensis* (333). As mentioned by Gregg (334), the presence of minute tesselation was not mentioned in the original description by Oldroyd. The ribs of *C. hastata pugetensis* are more rounded than those of *C. hastata,* those on each valve are nearly equal in size, and the fasciculi are minutely spinose. The interior of Recent shells is often ornamented, especially around the ventral margin, with dark red or red-orange color.

Chlamys hastata pugetensis is generally reported to be smaller than *C. hastata, C. h. ellisi* n. subsp., and *C. h. hericius.* Henderson (335), however, reported a specimen 77 mm high and long from deposits of Pleistocene age on Big Hope Island in Puget Sound.

We have examined six specimens from the type lot of *C. h. pugetensis,* the largest of which is 43 mm high. The minute tesselated sculpture on some of these occurs over nearly the entire valve but disappears near the ventral margin. Four other Recent specimens from Puget Sound, in the collections of the California Academy of Sciences, likewise bear this characteristic minute sculpture. We also have seen specimens from Duxbury Reef, Marin Co., and from Monterey Bay, California, which retain traces of this tesselated sculpture. One Recent specimen from Braca Point, Washington, 51 mm high, possesses typical sculpture of *C. h. pugetensis* until it is 26 mm high and then follows sculpture of minute oblique groovings such as that on C. *h. hericius,* which it resembles in general features.

Chlamys hastata pugetensis is reported living from Sitkalidak Island, off eastern Kodiak Island, Alaska, to Newport Bay, Califronia, from low tide to 91 meters (50 fathoms). It has been reported as a fossil by Gregg (1938) from strata of "presumably Pliocene" age, Deadman Island, San Pedro, California, and questionably by Grant and Gale (1931, p. 168) from strata of middle Pliocene age southeast of Pico Canyon, Los Angeles Co., California.

It appears that since Pliocene time the members of the *Chlamys hastata* group bearing honeycomb-like tesselations have been reduced to one subspecies, which is smaller, less numerous, and in general has become restricted to cooler waters.

Chlamys (Chlamys) jordani Arnold
Plate 30, Figure 10; Plate 32,
Figure 3 (cf.), 5, 6, 10, 12, 13

Pecten islandicus Müller, Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 29, 1878. Later Tertiary of San Diego. P. 29, on seacoast about 10 miles north of San Diego "(stratum c)." — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. Calif. State Mineral., p. 257, 1888. "Pl. — San Diego."

Not *Pecten islandicus* Müller, 1778.

Pecten (Chlamys) jordani Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 111, pl. 12, fig. 6, 7, June 27, 1903. — Arnold, U. S. G. S., Prof. Paper 47, p. 114, pl. 44, figs. 1, 1a, 1b ("Pliocene, Deadman Island, near San Pedro, Los Angeles County, Cal."), 1906. Also "Pacific Beach, San Diego (Arnold)," "Pliocene." — Arnold, U. S. G. S., Bull. 321, p. 32, pl. 14, figs. 5a, 5b, 1907. "Packards Hill". Also "Pliocene, Deadman Island, near San Pedro, Cal.; also found in the Fernando formation at Santa Barbara and elsewhere." "Pliocene." — B. L. Clark, Stratigraphy and Faunal Horizons of the Coast Ranges of California (Publ. privately), p. 28 (as "*Pecten jordani* Hertlein"), pl. 47, figs. 3, 4, (as "*Pecten (Chlamys) jordani* Hertlein"), 1929. (Copies of Arnold's illustrations, 1906). "Upper Pico formation of Ventura County," Pliocene.

Pecten jordani Arnold, McLaughlin and Waring, Calif. State Min. Bur., Map folio accompanying Bull. 69, inside of back cover, species 49, pl. 1, fig. 49, 1914. "lower San Pedro formation at Timm's Point, San Pedro, California," Pleistocene. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 55 (in part), 1924. "Pliocene of Santa Barbara, San Pedro, and San Diego." [Based upon Arnold's records. Not the record "Puget Sound," Recent.]

Type specimen. — No. 162, 522, United States National Museum.

Type locality. — "from the Pliocene of Deadman Island," San Pedro, California.

Range. — Middle to late Pliocene or early Pleistocene.

Occurrence in San Diego Fm. — C.A.S. 105, 1132, 1183, 12149, 28893. L.A.M. 107, 305.

Original description. — Shell of medium size, shape of *P. hericeus,* inequivalve, rather thin; right valve with twenty-five to thirty angular, smooth-topped, imbricated ribs, which become dichotomous after reaching a length of about 30 mm; interspaces deeply channeled and narrower than ribs; anterior ear imperfectly radially ribbed with six ridges, and showing elevated, concentric, incremental lines; posterior ear nearly obsolete, showing four ribs; byssal notch not deep; left valve shows twenty-five to thirty narrow, convex ribs, showing imbrications only slightly; interspaces as large as ribs; after a diameter of about 30 mm has been reached by the shell, small riblets appear in the widening interspaces; anterior ear shows five narrow, imbricated ridges, with wide interspaces; both valves show a tendency to contract suddenly at the basal

margin upon nearing completion of growth; surface of both valves covered with a minute, lattice-like sculpture, which is generally worn off on exposed portions of the shell. (Arnold.)

Dimensions. — Long. 42 mm; alt. 45 mm; diam. 15 mm; hinge 18 mm. (Arnold.)

Remarks. — Several earlier records of the occurrence of this species in Pliocene beds at San Diego appear to be based upon those of Dall, Cooper, and Arnold. Dall in 1878 cited *Pecten islandicus* from beds of Pliocene age at Pacific Beach and apparently this formed the basis of Cooper's record (1888) of that species in the Pliocene at San Diego. Arnold, 1906, indicated that Cooper's record was referable to *Chlamys jordani* Arnold.

Typical specimens of *Chlamys jordani* are quite rare. The type specimen from beds of late Pliocene or early Pleistocene age at San Pedro, California, was described as 45 mm high (336), 42 mm long; the umbonal angle approximately 95°. The valves are sculptured with 25-30 ribs which become dichotomous after reaching a length of about 30 mm. The ribs on the left valve are rather coarse and a short midrib appears in the interspaces after the valve has reached an altitude of about 30 mm. Both valves tend to contract toward the base.

Typical specimens of this species are higher than long and the general appearance is of a more slender shell than that of *Chlamys rubida.* As mentioned by Arnold, the right valve of *C. jordani* is similar to that of *C. rubida* but the ribs on the left valve are quite different. These reach to a height of about 20 to 30 mm, consist of simple, nonfasciculated, moderately coarse ribs covered with fine lattice-like sculpture but with only slight concentric imbrication.

One right and one left valve, the larger one 27.3 mm high, from Pacific Beach are smaller than the type of *C. jordani* and the ribs become dichotomous following a constriction of the shell when 20 mm high. One right and two small left valves, the largest one 17.5 mm high, from India and Upas streets in San Diego, develop a constriction when 16 mm high. The ribs and interspaces of all these valves are covered with very fine honeycomb-like reticulate sculpture.

One right and two left valves from Loc. 107 (LAM) are typical of *C. jordani* except for their larger size. The right valve is 47 mm high and has two constrictions in shell growth, one at 30 mm, and one at 42 mm. One left valve 34 mm high has a constriction at 20 mm, the other is 42 mm high (incomplete) and is gently contracted at a height of 29 mm. The ribbing on these left valves is dichotomous after the first constriction and, following this, the splitting of the ribs and the development of strong riblets in the interspaces result in more numerous finer ribs. Another feature on these left valves is a decided depression on the anterior ear where it joins the disk.

The only recent record of this species in beds of Pliocene age which we have noticed is that of Kundert (337) who cited it, provisionally, from the Los Angeles region. The specimens were not illustrated.

The specimen from beds at Timm's Point, San Pedro, California, which was illustrated by McLaughlin and Waring, is referable to *Chlamys jordani.* The specimen from the same locality illustrated by Woodring (338) differs in several important details from the type of *Chlamys jordani.* Woodring's specimen, a right valve, is almost as long as high and the umbonal angle is about 105° rather than 95°. The left valve was not illustrated.

Recent specimens identified by I. S. Oldroyd (339) with *Chlamys jordani* are not typical of that species and appear to be referable to the form described as *Pecten (Chlamys) hindsii kincaidi* I. S. Oldroyd (340). The same is true of the specimen illustrated by Grau (341) which he cited as *Chlamys rubida jordani* in the synonymy of which he placed *Pecten hindsii kincaidi* I. S. Oldroyd.

The smaller apical angle and consequently less elongate, less discoidal shape as well as the constriction followed by splitting of the ribs are characteristic features of *C. jordani* as shown on Arnold's illustrations of the type specimen. These shell characters, in our opinion, differ sufficiently from those of the form described as *kincaidi* to justify separation of the two.

Chlamys jordani has been cited as occurring in beds of Pleistocene age at various localities in southern California from San Pedro to Santa Barbara and as far north as British Columbia (342). Most of these records are not accompanied by illustrations, consequently no opinion is here advanced concerning the probable identification of the species but it is almost certain that most of them are not typical *C. jordani.*

Chlamys durhami Adegoke (343), described from the Santa Margarita Formation of late Miocene age in the Coalinga region, based upon a specimen 14.9 mm long and 17.9 mm high, sculptured with 20 to 22 dichotomous ribs, was compared by its author with *C. jordani.*

Several species occurring in beds of late Tertiary age in the northwest Pacific and Japan are members of the *Chlamys rubida* group, to which *C. jordani* belongs. Masuda (344) pointed out the differences separating *Chlamys jordani* from *Chlamys akitana* Yokoyama and *C. nisataiensis* Otuka, which occur in the late Tertiary of Japan.

Chlamys (Chlamys) opuntia Dall
Plate 30, Figure 5, 6

Pecten (Chlamys) opuntia Dall, Trans. Wagner Free Institute Sci., Vol. 3, Pt. 4, p. 707, pl. 29, fig. 6, April, 1898. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 113, 1903. "Found in the Pliocene at Pacific Beach, near San Diego." Also Pliocene at Packard's Hill, Santa Barbara, California. — Schuchert, Dall, *et, al.*, U. S. Nat. Mus., Bull. 53, Pt. 1, p. 490, 1905. "Pliocene. San Diego County, California." — Arnold, U. S. G. S., Prof. Paper 47, p. 118, pl. 41, fig. 2, 1906. "Pliocene. Pacific Beach, San Diego (Hemphill; Hamlin; Arnold.)." — Arnold, in Eldridge and Arnold, U. S. G. S., Bull. 309, pp. 152, 244, pl. 36, fig. 8, 1907. "Pliocene, Pacific Beach, San Diego County." Also Santa Barbara; Third Street Tunnel, Los Angeles. — Arnold, U. S. G. S. Bull. 321, p. 32, pl. 14, figs. 3, 4, 1907. "Fernando formation, Arroyo Burro, Santa Barbara," Pliocene. — Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, opp. p. 78, 1929. "San Diego Pliocene." — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 91, 1944. Earlier records cited.

Pecten opuntia Dall, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego." Also Fernando and Santa Barbara, Pliocene. — Carson, Pan-Amer. Geol., Vol. 43, No. 4, pp. 268, 269, 270,

1925. "San Diego fauna." Also Ventura Formation and Santa Barbara Formation, Pliocene.

Pecten (Pecten) opuntia Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 165, pl. 11, fig. 3 (Calabasas quad., Ventura or Los Angeles Co.), 1931. "Type locality: Middle Pliocene of Pacific Beach, San Diego." Also other records.

Chlamys opuntia Dall, Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, 1940 (1941). "Strata at Pacific Beach." San Diego. Upper Pliocene. — Woodring, Bramlette, and Kew, U. S. G. S., Prof. Paper 207, p. 80, 1946. "Based on material from the upper Pliocene part of San Diego formation at Pacific Beach . . . ." Also Lomita marl.

Type specimen. — No. 107752, United States National Museum.

Type locality. — "Pliocene of San Diego, California; Hemphill and Hamlin." Pacific Beach according to Arnold, 1906.

Range. — Middle and late Pliocene in southern California and northern Lower California. (Early Pliestocene in southern California (Woodring).

Occurrence in San Diego Fm. — C.A.S. 957, 1177, 1183, 1186. L.A.M. 107. S.D. 2931. Corner of Union and State streets, San Diego. S.U. Pacific Beach.

Original description: Allied to *P. hericeus* var. *navarchus* Dall, from which it differs by its smaller and not fasciculated radial ribs, more elongated anterior ear, more densely radially costate posterior ear, small size when adult, and by a tendency to be suddenly contracted at the basal margin on the completion of growth, somewhat as in *P. pesfelis.* Alt. 35 mm, lat. 32.5 mm. (Dall.)

A supplementary description by Arnold follows: Shell averaging about 35 millimeters in altitude, slightly shorter than high, subequivalve, equilateral (except for ears), both valves nearly flat until altitude of about 20 to 25 millimeters is reached, when they grow more convex; contracted at basal margin when adult; sides only slightly concave above. Right valve with 40 to 60 subequal, narrow, imbricated, more or less dichotomous ribs, which are separated by channeled interspaces about equal in width to the ribs; hinge line about two-fifths as long as disk; anterior ear much produced, sculptured by about six prominent, sharply imbricated radials, and imbricating incremental lines; byssal notch quite prominent; posterior ear nearly obsolete, radially and concentrically sculptured; whole surface of disk and ears sometimes microscopically checkered or tessellated. Left valve similar to right.

Dimensions. — Alt. 43 mm; long. 40 mm; hinge line 16 mm; diameter 12 mm; umbonal angle 78°. (Arnold, 1906.)

Remarks. — Several specimens, mostly single valves, typical of this species, are represented in collections from the San Diego Formation which we studied. A left valve from Loc. 107 (LAM), is 38.4 mm long and 43.6 mm high. Some specimens are more rounded than others. A left valve illustrated by Grant and Gale is 67 mm long and 69 mm high. The fine, uniform, non-fasciculated radial ribs are quite different from any other west American Pliocene species.

Some authors have considered this species to be a member of the *Chlamys islandica* group. It somewhat resembles some fine-ribbed variants of that group but the San Diego fossil is easily separable by its finer, even ribbing, slightly smaller umbonal angle, generally smaller size and tendency to constriction toward the ventral margin of adult forms. These features serve to separate it from forms of *C. rubida* and its close relatives.

The ribbing and the umbonal angle of *C. opuntia* are similar to those features on *C. hertleini* Loel and Corey (345), which was described from beds of early Miocene age. One decided difference in the two species is in the outline of the posterior ears. The posterior ears on *C. opuntia* slope obliquely downward from the hinge line whereas those on *C. hertleini* are squarely truncated.

Chlamys tamurae Masuda and Sawada (346), compared by its authors with *C. opuntia*, differs in that the surface of the left valve (and to a less degree the right valve) is folded forming low, broad corrugations. Furthermore, the illustration (see their fig. 12a) shows that the major ribs are divided toward the ventral margin of the right valve, a feature only occasionally present on *C. opuntia.*

In addition to the San Diego Formation in which the type specimen was found, *Chlamys opuntia* also has been recorded from beds of late Pliocene age north of Simi Valley, in upper Pico beds in Ventura Co., in Temescal Canyon near Santa Monica, in beds encountered in the Third Street Tunnel and elsewhere in Los Angeles, and in the Tijuana-Rosarito Beach area in northwestern Lower California. It also has been recorded from strata at Santa Barbara and in the Lomita Formation near San Pedro. These latter beds have been considered to be of late Pliocene age by some writers and early Pleistocene age by others. Grant (347) considered the Lomita Formation to be of late Pliocene age and he suggested that the sediment was deposited perhaps at depths of 30 to 90 meters (100 to 300 feet) and that the temperature was about 15° to 17° C. (60° to 62° F.)

Chlamys (Chlamys) rubida Hinds
Plate 35, Figures 6, 8

Pecten rubidus Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, p. 61, pl. 17, fig. 5, 1844 (January, 1845, on cover).

Not *Pecten rubidus* Martyn, Univ. Conch., 1784. [Nomenclatorially unavailable. See Opinion 456 Internatl. Comm. Zool. Nomencl., 1957.]

Pecten hindsii Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 606, August, 1864. Page 645, as *Pecten hastatus* ? var. *Hindsii.* Reprint in Smithsonian Misc. Coll., No. 252, pp. 92, 131, 1872. New Name for *Pecten rubidus* Hinds, not *Pecten rubidus* Martyn, 1784. Cited as occurring at Puget Sound; Vancouver Island; Straits of San Juan de Fuca, and adjoining shores. — I. S. Oldroyd, Stanford Univ. Pub. Univ. Ser. Geol. Sci., Vol. 1, p. 53, pl. 7, figs. 3, 4, 1924. (Copy of figures by Arnold, 1906). "Bering Sea to San Diego, California."

Pecten (?var.) *Hindsii* Carpenter, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, p. 58, April, 1865. "Hab. — In sinu Pugetiano juniorem legit U. S. E. E., adultum Kennerley: in insula Vancouver legit Lord."

Pecten hericeus var. *navarchus* Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 708, April, 1898. (New name for *Pecten rubidus* Hinds, 1844, not *Pecten rubidus* Martyn, 1784). "San Diego, California, at Pacific Beach, Hamlin," "Pleistocene" [Pliocene, according

to Arnold].

Pecten hastatus Sowerby var. *navarchus* Dall, Arnold, U. S. G. S., Prof. Paper 47, p. 112, pl. 43, figs. 1, 1a, 1b (Recent, Puget Sound), 1906. "Pliocene . . . Pacific Beach, San Diego. (Hamlin)." Also earlier records.

Pecten (Chlamys) hastatus Sowerby var. *hindsii* Carpenter, Arnold, U. S. G. S., Prof. Paper 47, p. 111, pl. 32, figs. 2, 2a (Recent, southeast Alaska), 1906. Pliocene to Recent.

Pecten (Chlamys) hindsii Carpenter, I. S. Oldroyd, Publ. Puget Sound Biol. Sta. (Univ. Washington), Vol. 4, p. 17, pl. 23, figs. 3, 4, 1924. (Copies of figures by Arnold, 1906). "Bering Sea to Cape San Lucas, Lower California" [Not the record "Cape San Lucas, Lower California."]

Pecten (Chlamys) hindsii navarchus Dall, I. S. Oldroyd, Puget Sound Biol. Sta. (Univ. Washington), Vol. 4, p. 17, pl. 26, figs. 2, 3, 1924. (Copies of figures by Arnold, 1906). "Bering Sea to San Diego, Calif."

Pecten hindsii navarchus Dall, I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 54, pl. 4, figs. 2, 3, 1924. (Copies of figures by Arnold, 1906). "Bering Sea to San Diego, California." Also Pleistocene.

Pecten (Pecten) islandicus Müller variety *hindsii* Carpenter, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 163, 1931. "Middle Pliocene; Pacific Beach, San Diego (Hamlin in Arnold)."

Pecten (Chlamys) rubidus Hinds, K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 69, pl. 3, figs. 4-6, 1958. [Carpenter's species discussed.]

Chlamys rubida Hinds, Grau, Allan Hancock Pac. Exped., Vol. 23, p. 76, pl. 24, 1959. "Bering Sea to Monterey, California. Also Pacific coast of Japan, as far south as 42° N." "Just below low tide to 100 fathoms." Also Pliocene and Pleistocene.

Chlamys (Chlamys) rubida Hinds, MacNeil, U. S. G. S., Prof. Paper 553, p. 21, pl. 20, figs. 7, 9; pl. 22, figs. 7, 8. 1967. Earlier records cited.

Type specimen. — Location unknown (Palmer, 1958). Originally in British Museum (Natural History).

Type locality. — "Inhab. Alashka, North-west America. At a depth of thirty-three fathoms."

Range. — Middle Pliocene to Recent. Recent from Bering Sea to Monterey (Grau), to Santa Rosa Island (Yates (348), California. Recent from just below tide to 183 meters (100 fathoms).

Occurrence in San Diego Fm. — C.A.S. 105, 957, 1132, 28893. L.A.M. 107. S.D. 54.

Original description. — Testâ subtrigono-orbiculari, inaequaliter duplo-convexâ, inaequiauriculatâ subtenui; valvâ sinistrâ convexâ, costis parvis numerosissimis, serratis, in fasciculos duarum triumve alternatè aggregatis, rufis, interstitiis pallescentibus; valvâ dextrâ subconvexâ, albidâ, costis majusculis, aggregatis; auriculis sulcatis, posticâ parvâ, obliquâ; intùs albâ.(Hinds.)

Remarks.—The right valve of *C. rubida* is sculptured with about 26 radial ribs which are wider than the interspaces, flattish-topped, smooth, and usually dichotomous. The interspaces are narrow, channeled, and sculptured with fine reticulate honeycomb-like tesselations. The left valve is sculptured with narrow, fasciculated ribs which are crossed by fine concentric imbrications, the interspaces are sculptured similar to those on the right valve. The ribs on the right valve increase by bifurcation, those on the left, at later stages of growth, by intercalation. The sculpture of this species is quite variable.

Recent specimens of *C. rubida* are often about 60 mm high but we have seen fossil specimens 70 mm high.

One large right and one left valve, and several smaller ones, of *C. rubida* are present in the collections from the San Diego Formation. The largest is a left valve, 59.9 mm long and 64.3 mm high, Cat. No. 4736 (SD), from India Street near Spruce Street, San Diego.

The radial sculpture on some valves in the present collection from Loc. 107 (LAM) is similar to that of the species of late Pliocene age described by Waterfall as *Pecten (Chlamys) islandicus picoensis* (349), and *Pecten (Chlamys) venturaensis* (350). Grant and Gale believed that the variation in sculpture in a series of *C. "hindsii"* is such as to embrace the forms named by Waterfall. MacNeil (1967, p. 28), however, considers *C. (C.) picoensis* to be a valid species, with two subspecies which were originally described in Japan.

Typical specimens of *C. rubida* differ from *C. islandica* in the generally smaller size, often less numerous primary ribs, and especially in the smaller posterior ears.

The shell of *C. rubida* differs from that of *C. jordani* in the fasciculate rather than simple ribs on the left valve, usually the lack of honeycomb-like tesselation on the tops of the ribs, and usually greater size.

Chlamys rubida usually has been cited in west American literature under the name of *Pecten* or *Chlamys hindsii.* Carpenter proposed a new name for the species described by Hinds and stated (1864, p. 606), " '*Pecten rubidus,* Hds.' Vanc. Is., *Lyall.* [Hind's type in Br. Mus. appears the ordinary form, of which *P. hastatus* =*hericeus* is the highly sculptured var. This shell, which is more allied to *Islandicus,* may stand as *P. Hindsii.*] (351)" In the same publication (p. 645) he stated, "*Pecten* (?var.) *Hindsii.* Broader; ribs close, small, smooth, bifurcating. Passes from *hastatus* toward *Islandicus.*" The following year Carpenter (1865, p. 58) gave the dimensions as "Long. 1.6, lat. 1.7, alt. .57", presumably referring to "Poll" (Pollex) as used on page 54. This indicates a height (beak to base) of approximately 40.51 mm.

The original illustration of *Pecten rubidus* is that of the exterior of a left valve, the ribs of which are fasciculated and crossed by fine concentric imbrications. The color is pink with concentric zones of lighter color. This illustration bears a resemblance to Arnold's illustration (1906, pl. 43, fig. 1a) of "*Pecten hastatus* Sowerby var. *navarchus* Dall." Carpenter (1864, p. 645) in a comparison with *P. hastatus* mentioned "In var. *rubidus,* Hds. (non Mart.), the ribs are equal, not serrated."

Palmer (1958, p. 70) called attention to the fact that the name *Pecten hindsii* Carpenter was based upon a specimen collected by Dr. Lyall at Vancouver and that Carpenter thought that this specimen was not identical with *Pecten rubidus* Hinds. She illustrated three right valves in the collection of the Redpath Museum which Carpenter identified as "*Pecten Hindsii* Cpr. = *rubidus,* H. C. Sitka." Unfortunately, the lack of left valves in the Redpath collection makes impossible comparison with the original illustration of the left valve of *P. rubidus* shown by Hinds.

Through the courtesy of F. Stearns MacNeil we have had the opportunity to examine the valves from the Red-

path Museum. The major ribs on these right valves are flattish and rather smooth on top and dichotomous toward the ventral margin. A right valve (see our pl. 35, fig. 8) from Loc. 107 (LAM) from the San Diego Formation is quite similar to the specimen illustrated by Palmer on her plate 3, figure 6. A similar development of ribbing is present on the form described as *Pecten (Chlamys) hindsii kincaidi* I. S. Oldroyd (352) from Puget Sound. The type of that species is a suborbicular shell which has flattish smooth topped ribs on the right valve and round topped ribs with only faint intercalaries on the left valve.

According to Palmer the type specimens of both *P. rubidus* and *P. hindsii* cannot be found. Considerable variation in sculpture is revealed in a series of specimens of this species complex and the relationship of the two is not definitely known at the present time. The specimens identified by Carpenter as "*Pecten hindsii,*" illustrated by Palmer, furnish some justification for retaining this form as a subspecies of *C. rubida* and this interpretation of Carpenter's species was proposed by MacNeil (U. S. G. S., Prof. Paper 553, p. 22, pl. 18, figs. 4, 6; pl. 19, figs. 1, 3, 4, 6; pl. 20, figs. 5, 6; pl. 21, fig. 4; pl. 22, figs. 1, 2; pl. 24, figs. 1, 8, 9, 1967). The two forms apparently represent extreme variants in the fine and coarse character of the ribs. The variation in sculpture of the fossils from the San Diego Formation is such that we assign to them the earliest name proposed for this group, at least until the relationship of the variants of this species complex is better known.

A right valve from the Gubik Formation, of Quaternary age in northern Alaska, which MacNeil (353) illustrated under the name of "*Chlamys hindsii*" was later described as *Chlamys (Chlamys) beringiana colvillensis* MacNeil (1967, p. 26, pl. 18, figs. 5, 7).

Pecten clemensae and *Pecten newcombi* of I. S. Oldroyd (354), *nomina nuda*, may be referable to *C. rubida* or to *C. rubida hindsii* or to the form described as *C. kincaidi.*

In the Japanese region, specimens referred to "*Chlamys islandica hindsi*" have been illustrated by Kira (355), and by Oyama and Takemura (356). According to Kuroda and Habe (357), this species occurs on the Pacific Ocean side of Japan from 42° to 55° North Latitude. We have not studied a series of specimens of the Japanese form but illustrations of specimens referred to *C. hindsii* from that region do not agree in detail with west American forms identified under that name. The record of Dautzenberg and Bavay (358) of *C. "hindsii"* in the Sulu Archipelago in the East Indies is referable to some other species (see Grau, 1959, p. 77).

The larger shell and flattish radial ribs on the right valve which are broader than their interspaces are features separating *C. rubida* from *C. imanishii* Masuda and Sawada (339) which was described from beds of Pliocene age in Japan.

Chlamys ingeniosa tanakai Akiyama (360) bears a resemblance to some forms of *C. rubida* as mentioned by Akiyama but we have not had specimens for careful comparison.

In addition to the occurrence of *Chlamys rubida* in strata of Pliocene age at San Diego, it was reported from Fourth and Broadway in Los Angeles by Willett (361), from the Ventura region by Waterfall (as *Pecten (Chlamys) islandicus picoensis* and *P. (C.) islandicus venturaensis),* and from the Ohlson Ranch Group in Sonoma Co. by Peck (362). Nomland (363) reported it as *Pecten hastatus hindsii* from the *Pecten coalingaënsis* zone of the Etchegoin Formation. Stewart (364) later reported fragments of "*C. cf. C. islandicus* (Muller)" from the *Acila* zone in the San Joaquin Formation in Kettleman Hills, but he did not record *C. rubida* from that area.

SUBGENUS *ARGOPECTEN* MONTEROSATO

Argopecten Monterosato, Jour. de Conchyl., Vol. 37 (Sér. 3, Vol. 29), No. 1, p. 20, 1889. Several species cited including "*Argopecten solidulus*, Reeve (*Pecten*, 1853). — Pl. 33, fig. 155. (Hab. ?) = *P. Philippii*, (non Michelotti, 1839, espèce fossile) Récluz, 1854 = *P. commutatus*, Monterosato, 1875. C'est aussi le *P. gibbus*, Philippi (non Lamarck). — Espèce Méditerranéenne et des Canaries." — Grau, Allan Hancock Pac. Exped., Vol. 23, p. 93, 1959. [Not "Type-species: *Pecten commutatus* Monterosato, 1875, p. 6." Concerning Grau's citation of type species see Keen, Veliger, Vol. 2, No. 4, p. 101, 1960.] — Waller, Jour. Paleo., Vol. 43, Suppl. to No. 5 (Paleo. Soc., Mem. 3), p. 32, 1969. Type, *Pecten solidulus* Reeve.

Plagioctenium Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 696, April, 1898. "Type *P. ventricosus* Sby." — Tucker-Rowland, Mém. Mus. Roy. d'Hist. Nat. Belgique, Deuxième Sér., Fasc. 13, p. 32, 1938. "Type. —*'Pecten' ventricosus* Sowerby =*C. gibbus circularis* Sowerby, by original designation, Dall, 1898."

Type species (by subsequent designation, Monterosato, Journ. de Conchyl., Vol. 47, No. 3, p. 193, 1899). — "Type: *P. solidulus*, Reeve = *P. Philippii*, Recluz (non Michelotti) = *P. commutatus*, Monts." Illustrated by Reeve, Conch. Icon., Vol. 8, *Pecten*, sp. 155, pl. 33, fig. 155, August, 1853. "Hab.-?)" — Kobelt, Syst. Conchyl. -Cab. von Martini und Chemnitz, Bd. 7, Abt. 2, *Spondylus* und *Pecten* p. 219, Taf. 58, fig. 8, 1888. [Copy of Reeve's illustration.] — Waller, 1969, p. 33, pl. 1, figs. 11, 12, 14, 15 (illustrations of holotype).

Range. — Early Miocene to Recent, worldwide in shallow, warm temperate and tropical marine waters.

Description. — Suborbicular, thick, sometimes large, equiconvex (right valve usually deeper) and with a tendency to oblique growth in adult; auricles large and nearly equal in length; ribs numerous, usually undivided, rounded or often squarish, crossed by concentric imbrications which are concave dorsally, or the ribs are frequently smooth; upper valve of Recent shells often richly colored with red or purple blotches.

Remarks. — Many American species of *Argopecten* have appeared in the literature under *Aequipecten* and *Plagioctenium.* This subgenus differs from *Aequipecten* in that the valves are nearly equally convex, the ribs and interspaces usually lack well developed radial lirae and there is a tendency toward obliquity in adult shells. Waller (365) published an extensive report dealing especially with the east American members of *Argopecten.*

The type species of *Argopecten, Pecten solidulus* Reeve, was based upon a juvenile shell. This species has been confused with *Pecten commutatus* Montersato, a name proposed for *Pecten philippii* Récluz, 1853 (not *Pecten philippii* Michelotti, 1839), a Mediterranean species.

More recently, Dr. F. K. North examined the type specimen of *P. solidulus* and found it to be quite distinct from *P. commutatus.* Dollfus (386) placed Reeve's species in the synonymy of "*Pecten (Chlamys) flabellum*" Gmelin, a west African species. Waller (1969, p. 33) believes that *P. solidulus* is probably referable to *P. circularis* Sowerby.

The shape, ribbing and coloration shown by Reeve's illustration of *P. solidulus* are similar to juvenile forms of *Pecten gibbus* as mentioned by Reeve.

It is unfortunate that the type species of *Argopecten* is based upon a juvenile shell, and information concerning the locality from which it came is lacking. However, the type specimen is preserved in the British Museum and its shell characters appear to be referable to one of the members of the well known *C. gibba-circularis* group. For that reason we have referred several west American species to *Argopecten* in the synonymy of which we include *Plagioctenium* which is better known for this group but which was published later than *Argopecten.*

Argopecten includes, among others, the well known late Cenozoic American *C. circularis-gibba-irradians* group. It is well represented in the Caribbean region where F. and H. Hodson recorded subspecies of *C. circularis* from the Miocene and the Pliocene of Venezuela. Other species occur in the late Cenozoic of the Atlantic and Gulf coasts of eastern United States as well as in the Antilles and northwest Africa. Probably some species in other regions may be referable to this subgenus. Speciation in this group progressed rapidly during the Pliocene period.

The earliest representative of *Argopecten* recorded from western North America is *Chlamys (Argopecten) neahensis* Arnold (367) from beds of middle Miocene age in Washington. We have examined a cast of the type specimen and we agree with Arnold's conclusions concerning its similarity to *C. circularis.* We find no reason to place it doubtfully in the synonymy of a species of *Lyropecten* as was done by Grant and Gale (1931, p. 184). Other than inspection of this cast we have not seen specimens of this species. Weaver (1943), however, reported it from the general area from which the type came. This is the only species reported up to the present time from the Miocene of western North America which is definitely referable to *Argopecten* but this subgenus was represented by a number of species during Pliocene time in southern California and Lower California and in more southern regions. At the present time two species *(C. purpurata* and *C. circularis)* and one subspecies *(C. circularis aequisulcata)* live in tropical and subtropical west American waters. Other species live in the western Atlantic, west Africa, and elsewhere.

From the known occurrences of species, one may infer that *Argopecten* had its origin in tropical or temperate waters in early Miocene time.

Chlamys (Argopecten) abietis abbotti n. subsp.
Plate 34, Figure 5; Plate 36, Figures 1, 6

Type specimen. — Holotype in the type collection of the San Diego Society of Natural History.

Type locality. — From cut in exposure at Frontier Housing Project, Loma Portal, San Diego, California; Patrick Hanratty collector, April, 1945.

Additional localities in San Diego Fm. — C.A.S. L.A.M. 302A, P.87: No. 8325. S.D. 409.

Description. — Shell large, thick, both valves highly convex, somewhat elongated posteriorly; hinge line long, a little over two thirds the length of the valves. Right valve with 21 radial ribs which are high, narrowly flat-topped and steeply sloping until the valve is about 70 mm high, then becoming lower and broadly rounded; the sides of the ribs and the interspaces are ornamented with close-set fringing lamellae; anterior ear sculptured with 4 or 5 fine radial riblets, a well developed byssal notch present; posterior ear faintly radially striated and with lines of growth which reveal a shallow sinuation. Left valve with ribbing similar to that of the right except that the ribs are narrower and more triangular, the anterior ear with a shallower notch and with faint traces of fine riblets. Inner margin of valves scalloped by the corresponding ribs and interspaces on the exterior. Dimensions: length 129.0 mm, height 118.0 mm, convexity (both valves together), 64.0 mm, length of hinge line 88.0 mm.

Remarks. — The shell characters of this new subspecies appear to be intermediate between those of *Chlamys (Argopecten) abietis* E. K. Jordan and Hertlein (368) and those of *C. (A.) circularis aequisulcata* Carpenter (369). This new subspecies differs from *C. (A.) abietis* in the deeper notch under the right anterior ear, in the more widely spaced ribs and by the more flattened character of the ribs toward the ventral

Key to Species and Subspecies of *Argopecten*

A. Valves highly and nearly equally convex
  a. Major ribs of right valve (22) with small riblet at base on each side . . . . . *ericellus*
  aa. Major ribs of right valve (18 to 21) lacking riblet at base
    b. Ribs on left valve rounded . . . . *circularis*
    bb. Ribs on left valve triangular . . . . *abbotti*

B. Valves moderately convex, the left decidedly more so
  a. Ribs 18 to 22; shell of moderate size
    b. Ribs 18 to 21; ribs decidedly widened toward ventral margin . . . . . *invalida*
    bb. Ribs 21 to 22; ribs not decidedly widened toward ventral margin
      c. Ribs low, rounded, subobsolete toward ventral margin . . . . . *subdola*
      cc. Ribs squarish, high, retaining this character to ventral margin . . . . . *callida*
  aa. Ribs 24 to 27; shell large, coarse, thick . . . . . *hakei*

margin of the left valve. It differs from *C. (A.) circularis aequisulcata* in the larger, thicker shell, longer hinge line, more triangular shape of the ribs in the early stages of growth but which become rounded and flattened toward the ventral margin on the right valve, and also in the more highly convex left valve with narrower interspaces between the ribs.

The rotund appearance of large specimens of this new subspecies lends a general resemblance to *C. (A.) hakei* Hertlein but it may be separated from that species by the fewer ribs (21 or 22 rather than 24 to 27) which are triangular until the shell is about 70 mm high and then become broader and flatter toward the ventral margin.

A large, thick, left valve in the collections of the Los Angeles County Museum, collected by Charles Sternberg at 32nd Avenue and Woolman Street, San Diego, is 105 mm long, 96 mm high, the convexity about 27 mm. It is sculptured with 21 ribs. The interior is reddish-brown in color especially the ventral half of the valve. The shell is partially covered with hard, gray, fine grained sandstone. Small oysters are attached to the exterior of the valve as might occur if the empty shell lay upon the sea bottom for a time before it was covered with sediment. The very large size of this valve and the traces of coloration on the interior are similar to those of *C. (A.) c. aequisulcata* Carpenter but the size and thickness correspond more with those of *C. (A.) abietis abbotti* and we refer it provisionally to this subspecies.

Two specimens from Loc. 595 (UCLA), about two miles north of Somis, Ventura Co., California, in a *Pecten* reef apparently near the base of the Long Canyon Member of the Las Posas Formation, of late Pliocene age, are quite similar to the type specimen of *C. (A.) abietis abbotti* but the ribs are slightly broader. The larger specimen is 141.5 mm long, 132.6 mm high, the convexity (both valves together), 61 mm. A smaller specimen collected with the two large fossils from Ventura County, is 74 mm long, 69.6 mm high, the convexity (both valves together), 34 mm. The ribs on this specimen, especially on the left valve, are triangular with fringing lamellae, corresponding in every way with typical *C. (A.) abietis* of the same size from Lower California.

This subspecies is named for Clinton G. Abbott, former Director of the Museum of the San Diego Society of Natural History, whose encouragement to the authors during the preparation of the early portion of this memoir is greatly appreciated.

Chlamys (Argopecten) circularis Sowerby
Plate 32, Figures 4, 15, 16

Pecten tumidus Sowerby, Proc. Zool. Soc. London for 1835, p. 109, October 9, 1835. "Hab. ad Sanctam Elenam et ad Salango, Columbiae occidentalis. Found in sandy mud at from six to ten fathoms."

Not *Pecten tumidus* Turton, 1822.

Not *Pecten tumidus* Hartmann in von Zieten, 1833.

Pecten circularis Sowerby, Proc. Zool. Soc. London for 1835, p. 110, issued October 9, 1835. "Hab. ad Sinum Californiae. (Guaymas)." "Found in sandy mud at a depth of seven fathoms." — Sowerby, Thes. Conch., Vol. 1, *Pecten*, p. 51, pl. 12, fig. 23, 1842.

Pecten ventricosus Sowerby, Thes. Conch., Vol. 1, p. 51 pl. 12, figs. 18, 19, 26, 1842. A new name for *Pecten tumidus* Sowerby, 1935. Not *Pecten tumidus* Turton, 1822, nor *Pecten tumidus* Hartmann in Zieten, 1833. — Reeve, Conch. Icon., Vol. 8, *Pecten*, species 31, pl. 7 figs, 31a, 31b, 1852. Not the locality "Philippine Islands."

Pecten (Plagioctenium) circularis Sowerby, Arnold, U. S. G. S., Prof. Paper 47, p. 125, pl. 42, figs. 3-6; pl. 44, figs. 6, 6a, 6b, 7, 1906. "Pliocene (?). Cholas Valley, near San Diego (Stearns)." Also Pleistocene. Recent from the Gulf of California to Santa Elena, Ecuador. — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 439, 1926. "The San Diego Pliocene at Pacific Beach, near San Diego, California."

Aequipecten (Plagioctenium) circularis Sowerby, Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 72, fig. 132, 1958. Gulf of California to Paita, Peru. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 163, pl. 19, figs. 2, 2a, 2b, 1961. Recent, Lower California to northern Peru.

Chlamys (Argopecten) circularis Sowerby, Grau, Allan Hancock Pacific Exped., Vol. 23, p. 97, pl. 32, 1959. Cedros Island, Lower California, Mexico, to Paita, Peru, and the Galápagos Islands, at depths from 4 feet to 75 fathoms. Also, ?Pliocene and Pleistocene.

Type specimen. — No. 1950-11-14.18.19., British Museum (Natural History).

Type locality. — "Hab. ad Sinum Californiae. (Guaymas)." "Found in sandy mud at a depth of seven fathoms".

Range. — Middle Pliocene to Recent. Recent from Cedros Island, Lower California, Mexico, to Bayovar, Peru, and the Galápagos Islands, in 1 to 137 meters (1 to 75 fathoms). "Found on rock, gravel, sand, sandy mud bottoms; associated with kelp, corallines or gorgonians." (Grau.)

Occurrence in the San Diego Fm. — C.A.S. 1132, 1137. L.A.M. 305, 305A, 320, 320A. S.D. 412. U.C.L.A. 306.

Original description. — Pect. testâ suborbiculari, tumidâ, subaequivalvi, aequilaterali, fusco alboque variâ, auriculis magnis, subaequalibus; costis radiantibus octodecim interstitiis latioribus, arcuatim striatis; valvâ alterâ sulcis profundioribus: long. 1.5, lat. 0.8, alt. 1.4 poll. (Sowerby.)

Remarks. — About 45 specimens, mostly single valves, are here referred to *Chlamys circularis*. A right valve from Loc. 320 (LAM), near the Mexican boundary, is 84 mm long, 83.5 mm high, the convexity (one valve) about 28 mm. Another right valve from Loc. 1137 (CAS), corner of Logan Avenue and 31st Street, San Diego, is 49.5 mm long. Many smaller, well preserved valves also occur with these larger specimens. An interesting feature of many of these fossils is that they retain traces of coloration.

The larger valves are definitely referable to *Chlamys circularis*. In the smaller valves, there is much variation in the convexity, the width of the interspaces between the ribs and in the height and degree of rounding or flattening of the tops of the ribs. Many of the valves to a height of about 35 mm are very convex, the ribs are high and flat-topped and rather closely spaced. These closely resemble Arnold's illustration (1906, pl. 44, fig. 7) of the type of *Pecten compactus* Dall which is now generally placed in

the synonymy of *C. circularis.* Other larger ones resemble Arnold's illustration of *C. circularis* (on his plate 42, fig. 3). Large specimens of *C. circularis* from the Gulf of California are about 66 mm long.

Some of the small specimens resemble *C. (A.) circularis aequisulcata* Carpenter (370), but the shells are somewhat thicker, the ribs are wider and the coloration appears to have been more pronounced than on the subspecies. A comparison of these small fossils with a series of specimens of Recent *C. (A.) circularis* from tropical west American waters reveals similar convexity and ribbing in the early stages of the Recent species.

Recent adult specimens of *C. (A.) circularis aequisulcata* differ from typical *C. (A.) circularis* in the larger, flatter, and thinner shell as well as in the narrower ribs and less brightly colored shell.

Chlamys circularis is very similar to the Recent east American species, *C. gibba* Linnaeus (371), but differs in details, especially in the decided angulation delimiting the posterior ear from the disk on the right valve. Davenport (372) made a comparative study of a large number of specimens of these two species from the east and west coasts of North America and found some difference in the convexity and in the less obliquity of the west coast form. The two species are undoubtedly members of a closely related group but we do not consider them to be identical.

Several species and subspecies allied to the *C. gibba-circularis* group have been described from strata of late Miocene and Pliocene age in southeastern United States. These have been discussed by Tucker-Rowland, by Mansfield, and by Waller. Weisbord (373) recently discussed thirteen species and subspecies of this group.

Some of the fossils from the San Diego formation closely resemble some specimens of the form described as *Pecten (Plagioctenium) calli* Hertlein (374) from beds of Pliocene age at Bahía Tórtolo (Turtle Bay), Lower California. The record of this form from the San Diego Pliocene, mentioned by E. K. Jordan and Hertlein, is referred by us to juvenile *C. circularis.* Typical specimens of the form *C. c. calli* possess very highly arched umbos, squarish ribs on the right valve and fine, high ribs on the left valve. There is also a tendency for the valves to develop a length greater in proportion to the height. Durham (375) mentioned this tendency in *C. circularis* occurring in Pliocene beds in the Gulf of California region. The valves of *C. circularis calli* are more elongated and the ribs are more numerous and narrower than those of *C. circularis bramkampi* Durham (376) described from the Carrizo Creek region in Imperial County, which has about 19 ribs.

In general appearance and in degree of globosity, some of the smaller specimens from San Diego resemble *C. eldridgei* Arnold (377) which was described from beds of late Pliocene age in San Joaquin Valley, California. The fossils from San Diego have thinner shells, which lack constrictions, the ribs are more numerous, often a little more widely spaced and the crenellations along the ventral margin of the interior are less consistently and deeply grooved than those of *C. eldridgei.* The ribs on some of the left valves of *C. eldridgei* are shallowly medially grooved toward the ventral margin but this feature is lacking on the valves from San Diego.

Some of the present specimens bear a resemblance to *Chlamys deserti* Conrad (378) but differ from typical specimens of Conrad's species. The original description of *Chlamys deserti* was based upon a left valve with 23 ribs. Arnold (379) illustrated specimens from Carrizo Creek, the type locality of *C. deserti,* and mentioned the correct number of ribs.

Grant and Gale (1931, p. 212) cited the number of ribs on the *deserti* group "usually 18 or 19", and on typical *deserti* 15 to 19. Woodring and Stewart (1941, p. 91) stated that *C. deserti,* had fewer ribs than *P. impostor* which originally was described as possessing 21 to 24. It appears obvious that some of the specimens attributed to *C. deserti* are not referable to it. Judging from the original description given by Conrad, the left valve illustrated by Arnold (1906, pl. 26, fig. 3), the illustrations of Nomland (1917, pl. 6, figs. 1, 1a, 1b), those of Hanna (1926, pl. 25, figs. 1, 2, 3), and of Durham (1950, pl. 11, figs. 5, 6) correctly delineate typical specimens of Conrad's species.

The present fossils from San Diego are more elongate than typical *C. deserti,* they have fewer ribs, the submargins are wider and not sculptured with riblets and the ears are more concave. They are referable to the variable species, *C. circularis.*

Several members of the *C. circularis* group have been described from strata of Miocene age. The species described as *Pecten (Plagioctenium) neahensis* by Arnold (1906, p. 87, pl. 15, fig. 2, 2a, 2b) from beds of Miocene age at Neah Bay, Washington, has narrower ribs and a longer hinge line than *C. circularis.* The type specimen is definitely referable to *Argopecten* as mentioned in our discussion of that subgenus.

Three subspecies of *C. circularis* were described by F. and H. Hodson, from beds of Miocene and Pliocene age in the Caribbean region. These were described as *Pecten circularis cornellanus* (380), Miocene; *Pecten circularis venezuelanus* (381), Miocene and Pliocene; and *Pecten circularis caucanus* (382) of Pliocene age. These were said to generally differ from typical *Chlamys circularis* in details of sculpture but that intergradation exists with that species. Another member of this group described as *Pecten (Plagioctenium) demiurgus* by Dall (383) (to which species Grant and Gale referred some west American records of *C. circularis)* from strata of late Miocene age in Trinidad, has higher, narrower umbones and the ribs are said to be wider and more closely spaced than those of the Recent west American species.

Chlamys (Argopecten) callida Hertlein
Plate 32, Figures 9, 11

Pecten (Plagioctenium) callidus Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 1, p. 22, pl. 5, figs. 1, 3, 5, 6, July 21, 1925. — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 437, 1926. "San Diego Pliocene of Pacific Beach near San Diego, California." Also Cedros Island and Turtle Bay, Lower California, Pliocene.

Pecten (Aequipecten) purpuratus Lamarck variety *callidus* Hertlein, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 211, pl. 5, fig. 4 (Fernando Pass, Los Angeles Co., 1931. "San Diego (Stanford collection)." Pliocene.

Type specimen. — No. 53, Stanford University, Department of Geology, Type Collection.

Type locality. — "Cedros Island, Lower California." "Salada, Pliocene."

Range. — Middle Pliocene of southern California and northern Lower California.

Occurrence in San Diego Fm. — C.A.S. 105, 1138, 1413, 1414, 12145. L.A.M. 122, 127, 305.

Original description. — Shell of medium size, the valves moderately arched. Right valve ornamented by about 21 or 22 rather high, flat-topped, radiating ribs separated by narrower interspaces, tops of ribs smooth, but sides and interspaces sculptured by fine, sharp lamellae; anterior and posterior margins sculptured by concentric lines of growth only; ventral margin rounded; ears unequal, the anterior with a large byssal notch and ornamented by about five or six radiating riblets crossed by concentric lines of growth; the posterior sculptured by several radiating riblets. Left valve more convex than right and somewhat one-sided in appearance, with sculpture quite similar to that of right valve except that the interspaces are slightly wider; anterior ear carrying a small, rounded notch and ornamentation consisting of small, radiating riblets and concentric lines of growth; posterior ear sculptured much as the anterior. Altitude 55 mm; longitude 55 mm; diameter 19 mm; apical angle of valves approximately 105°. (Hertlein.)

Remarks. — Several specimens of *Chlamys callida* are present in collections from Pliocene beds at Pacific Beach. One of the largest of these is 55.5 mm long; 53.5 mm high; convexity (both valves together) 19.6 mm; length of hinge line 30.5 mm; umbonal angle 105°.

The shell of this species is characterized by the gently convex right valve and sculpture consisting of 21 to 22 well developed flat-topped ribs which are separated by narrower interspaces. The left valve is more convex than the right, but is similarly sculptured except that the ribs are narrower and separated by wider interspaces.

The outline and general sculpture of this species is similar to that of *Chlamys subdola*, but it differs from that species in the much higher flat-topped ribs which retain this character to the ventral margin.

The greater size, greater number of flat-topped ribs which retain this character to the margin, the lack of interrupted concentric zones of growth and the greater umbonal angle, are features which serve to separate *C. callida* from *C. invalida*.

To the north of San Diego, *Chlamys callida* has been reported by Grant and Gale as occurring in beds of Pliocene age in the Los Angeles region. To the south it is known to occur at Cedros Island and at Bahía Tórtolo (Turtle Bay) on the west coast of Lower California. It has been recorded by Vokes (384) as occurring in the Gloria Formation of middle Pliocene age and in the Infierno Formation of late Pliocene age in the Santa Rosalia district on the east coast of Lower California. The specimen cited by Hanna and Hertlein under the name of this species from San José Island in the Gulf of California is not typical of *C. callida*.

Chlamys (Argopecten) ericellus Hertlein
Plate 32, Figure 7

Pecten (Plagioctenium) ericellus Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 18, No. 5, p. 215, pl. 24, figs. 10, 11 (in No. 8), April 5, 1929. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 85, 1944. Original record cited.

Type specimen. — No. 2998, California Academy of Sciences, Department of Geology, Type Collection.

Type locality. — "Pacific Beach, San Diego, California." "San Diego Pliocene."

Range. — Known only from the type locality.

Occurrence in the San Diego Formation. — California Academy of Sciences: Loc. 1132, Pacific Beach (Sternberg Loc. 34).

Original description. — Shell small, moderately convex; hinge line straight. Right valve ornamented by about 22 subrounded, fairly low radiating ribs which are separated by narrower interspaces; two tiny midribs are present along the base of the sides of the major ribs; ribs and interspaces crossed by concentric lines of growth; anterior and posterior margins ornamented by concentric lines of growth; ventral margin rounded; ears unequal, the anterior with a well-defined byssal notch, and sculpture of about five or six radiating riblets crossed by incremental lines; the posterior ear sculptured by about four or five radiating riblets crossed by lines of growth, no notch present. Altitude 28 mm; longitude, 29.1 mm; diameter of right valve approximately 7.5 mm; apical angle in right valve approximately 94°. (Hertlein.)

Remarks. — The shell of this species is characterized by its narrow, subrounded ribs, narrow interspaces, and by the presence of two tiny riblets, one at the base of each side of most of the major ribs. In some of the interspaces toward the lateral margins only one riblet, or in some cases, none is present.

This form appears to be a member of the *Chlamys circularis* group. It differs from *C. circularis* in the smaller posterior ear, more numerous, narrower ribs and interspaces, and in the presence of the riblets in the interspaces toward the ventral margin.

Grant and Gale (1931, p. 219) stated that this form could be matched by juvenile specimens of *Chlamys circularis aequisulcata* Carpenter. However, they cited it with question in the synonymy of "*Pecten (Aequipecten) gibbus* variety *circularis* Sowerby." Comparison of the type specimen of *C. (A.) ericellus* with a series of specimens of *C. circularis* and its subspecies *C. circularis aequisulcata* of comparable size, reveals differences sufficient in our opinion to justify assignment of specific status to *C. (A.) ericellus*.

Chlamys (Argopecten) hakei Hertlein
Plate 33, Figure 10

Pecten (Plagioctenium) hakei Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 1, p. 18, pl. 4, figs. 1, 3, July 21, 1925. — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 440, pl. 31, figs. 1, 2 ("Cedros Island" and "Turtle Bay", Lower California; Pliocene), 1926.

Pecten (Aequipecten) purpuratus Lamarck variety *hakei* Hertlein, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 209, pl. 8, fig. 3, 1931. Type specimen illustrated. Earlier records cited. Cited from "San Diego formation (Hertlein and Grant)," also from Pliocene of Lower California and Ventura Co., California.

Type specimen. — A right valve, No. 40, Stanford

University, Department of Geology, Type Collection.

Type locality. — "Turtle Bay, Lower California," Salada, Pliocene.

Range. — Middle Pliocene of southern California and northern Lower California.

Occurrence in San Diego Fm. — L.A.M. 124. S.D. 4413.

Original description. — Shell moderately arched, coarse and thick, slightly longer than high. Right valve ornamented by about 23 or 24 rounded to slightly flat-topped ribs, separated by narrower, round-bottomed interspaces, both the interspaces and ribs crossed by concentric incremental lines, and, in some cases, by rather strong lines of growth; anterior ear with a large byssal notch, and sculpture consisting of about five or six radiating riblets, crossed by concentric incremental lines; anterior and posterior margins of valves smooth except for concentric incremental lines; ventral margin rounded; posterior ear ornamented by about eight radiating riblets and by lines of growth, the posterior edge of the ear forming nearly a right angle with the hinge line. Left valve convex, higher at the umbo than the right valve, and ornamented by about 24 or 25 squarish, flat-topped, rounded ribs, separated by narrower, round-bottomed interspaces, the whole valve sculptured by concentric lines of growth; ears slightly concave, ornamented by about six or seven radiating riblets. Altitude 90 mm, longitude 95 mm, diameter of right valve approximately 15 mm; apical angle of right valve, approximately 114°. (Hertlein.)

Remarks. — A large, well preserved specimen of *Chlamys hakei* was collected at Pacific Beach by Dr. E. C. Wilson, San Diego Society of Natural History. It is 152 mm long, 135 mm high, the convexity (both valves together) 55 mm. It is sculptured with about 27 radial ribs and it agrees in all shell characters with specimens from beds of Pliocene age on Cedros Island. A large left valve in the collections of the San Diego Society of Natural History, from Juniper and Boundary streets, San Diego, is 160 mm long, 142 mm high, convexity approximately 35 mm. A fragment of an imperfectly preserved left valve in the collections of the Los Angeles County Museum, which came from strata 15 feet below Snyder's Continuation school in San Diego, is provisionally referred to *C. hakei.*

This species is characterized by its large, thick, coarse valves which are sculptured with 24 to 27 subrounded radial ribs.

The shell of this species can be separated from other somewhat similar west American species of *Argopecten* by its large size when adult and by the more numerous subrounded radial ribs. In the number of ribs it is exceeded by *Chlamys (Argopecten) evermanni* E. K. Jordan and Hertlein (1926, p. 439, pl. 27, fig. 1) which has 30 to 31 flattish topped ribs separated by very narrow interspaces. *Chlamys hakei* differs from *C. cristobalensis* Hertlein (385) in the much wider and less elevated ribs. *Chlamys hakei* differs from *C. purpurata* Lamarck (386) now living from Paita, Peru, to Valparaiso, Chile, in the generally larger size, larger ears, generally more numerous, rounded ribs which are separated by narrower interspaces. The ribs on the right valve of *C. purpurata* are flat-topped and on both valves the ribs are separated by rather deeply grooved interspaces, those on large left valves often with an interstitial riblet.

Chlamys hakei can be easily separated from *Chlamys (Lyropecten) cerrosensis* by the more numerous ribs, lack of coarse hinge teeth, lack of midrib in interspaces and also by the fact that the ears on the left valve slope downward from the margin rather than forming a right angle.

In addition to the present record of *Chlamys hakei* in beds of Pliocene age at San Diego, it occurs at Cedros Island and at Bahiá Tórtolo (Turtle Bay), Lower California. Grant and Gale recorded this species as occurring in beds of Pliocene age one and one half miles west of Somis in Ventura Co. but that record needs substantiation.

We are uncertain what species is represented by the record of "*Pecten purpuratus* var." cited by Woodring (387) from beds of Pliocene age in Temescal Canyon, Los Angeles Co., California, or by records of that species from the same county which were listed by Oakshott (388), and by Winterer and Durham (389). Vokes (390) reported "*Aequipecten purpuratus*" from strata of late Pliocene age and "*Aequipecten* cf. *purpuratus*" from beds of Pleistocene age in the Santa Rosaliá region in Lower California. However, Durham, 1950, did not record that species in collections from the Gulf of California region studied by him nor, more recently, did Emerson and Hertlein (Trans. San Diego Soc. Nat. Hist., Vol. 13, No. 17, pp. 333-338, 1964). It appears certain that records of *C. purpurata* from western North America are referable to some other species.

Chlamys (Argopecten) invalida Hanna
Plate 33, Figures 1, 3, 8

Pecten (Plagioctenium) cooperi Arnold, U. S. G. S., Prof. Paper 47, p. 124, pl. 49, figs. 2, 3, 4, 1906. San Diego Formation, Pacific Beach, San Diego, Pliocene. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 83, 1944. Arnold's record cited.

Pecten cooperi Arnold, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 151, 1919. "San Diego." Pliocene.

Not *Pecten cooperi* E. A. Smith, Fauna and Geography of Maldive and Laccadive Archipelago, Vol. 2, Pt. 2, Moll., p. 621, pl. 36, figs. 15-18, 1903. Felidu Atoll, Maldive Islands, in 1 to 35 fathoms.

Pecten invalidus Hanna, Proc. Calif. Acad. Sci., Ser. 4, Vol. 13, No. 10, p. 177, March 18, 1924. New name for *Pecten cooperi* Arnold, 1906, not *P. cooperi* E. A. Smith, 1903. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 88, 1944. "[San Diego,] Pliocene. Pacific Beach, San Diego Co."

Pecten (Plagioctenium) invalidus Hanna, E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 441, 1926. "San Diego upper Pliocene of southern California." Also records from Lower California.

Pecten (Aequipecten) deserti Conrad variety *invalidus* Hanna, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 213, 1931. "Pacific Beach, San Diego (Arnold; Hertlein and Grant)." Pliocene.

Aequipecten circularis invalidus Hanna, Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, 1940 (1941). Pacific Beach, San Diego, California, Pliocene.

Aequipecten invalidus Hanna, Vedder, U. S. G. S., Prof. Paper B-400, p. B327, 1960. "San Diego formation." Also Niguel Formation and others.

Type specimen. — No. 8, Stanford University, Department of Geology, Type Collection.

Type locality. — "San Diego formation (Pliocene), Pacific Beach, San Diego County, Cal."

Range. — Middle Pliocene of San Diego, California, and northwestern Lower California.

Occurrence in San Diego Fm. — C.A.S. 104, 105, 1130, 1132, 1138, 1179, 1199, 1399, 1413, 12145, 34025. L.A.M. 122. U.C.L.A. 302, 2420.
three miles south of La Jolla, Pacific Beach; Locs. 105; 1130, 1138, [Sternberg's Loc. 3]; 1199; 12145; 35025 Pacific Beach; Loc. 1132, above Loc. 1130; Loc. 1179, upper portion of lower beds exposed in Pliocene section

Original description of *Pecten (Plagioctenium) cooperi* Arnold. — Shell averaging about 30 millimeters in altitude, slightly longer than high, both valves moderately convex, disks slightly obliquely produced posteriorly, moderately thick; disk generally characterized by several more or less prominent concentric zones of interrupted growth, which show as color bands even on the fossil shells; sides nearly straight; margins serrate. Right valve with 18 to 20 flat-topped, squarish ribs, which tend to flatten out and become more convex topped in the later stages of growth; interspaces narrower than the ribs, and crossed on the bottom by numerous, fine, sharp, incremental lirulae, which become obsolete on the ribs excepting in the later stages of growth; hinge line somewhat more than one-half length of disk; anterior ear slightly produced and ornamented by 4 or 5 prominent radials and numerous incremental lines; byssal notch deep and sharply defined; posterior ear slightly truncated, and sculptured by obsolete radials and fine incremental lines. Left valve similar to right, except that the ribs are narrower and the interspaces correspondingly broader. Dimensions: Alt. 30 mm; long. 31 mm; hinge line 17 mm; diameter 12 mm; umbonal angle 95°. (Arnold.)

Remarks. — A number of specimens all from Pacific Beach, the type locality of *Chlamys invalida*, agree in all shell characters with the type specimen.

Valves of this species are characterized by their low convexity and by the character of the ribs, 18 to 20, which are square in the early stages but which widen out and become more convex toward the ventral margin. The interspaces often are ornamented with well developed concentric imbrications.

A typical right valve from Loc. 1179 (CAS), Pacific Beach, is 35.2 mm long, 33.5 mm high, convexity (one valve) 9 mm, umbonal angle 95°. Two large right valves, from Loc. 105 (CAS), the larger 47.9 mm long and 46.8 mm high, agree with valves of *Chlamys invalida* except that they are larger and have a greater number of ribs, 21 to 22. These valves appear to be referable to large gerontic forms of *C. invalida*.

The smaller shell, more rounded outline, fewer ribs which become broader and more rounded toward the ventral margin, occasional concentric zones of interrupted growth, and smaller umbonal angle are features which serve to separate this species from *Chlamys callida*.

The generally smaller more orbicular shell and fewer ribs which become decidedly broader and more convex but not obsolete near the margin are characteristics which serve to separate *C. invalida* from "*Aequipecten*" *antonitaensis* Durham (391) which was described from beds of middle Pliocene age at Punta Santa Antonita on the east coast of Lower California.

Chlamys invalida has also been reported from Cedros Island and the west coast of Lower California. Records of it in the Gulf of California region are, in most cases, open to doubt. Specimens from beds of Pliocene age in the Los Angeles region which were attributed to this species by Grant and Gale (1931, pl. 5, figs. 5a, 5b, 5c, 6a, 6b, 6c) are not typical of *C. invalida* but bear a greater resemblance to some forms of *C. deserti* Conrad or of *C. circularis*

Chlamys (Argopecten) coopericellus Ferreira (392), described from strata of early Miocene age in Brazil, was compared by its author with "*C. (A.) cooperi* (Arnold, 1906)" [= *Pecten invalidus* Hanna]. A small riblet is present in the interspaces between the ribs of the Brazilian species and in this and in other details it is quite distinct from *C. invalida*.

Kryshtofovich (393) reported "*Pecten cooperi*" as occurring in the "Upper oil bearing series" of Pliocene age on Sakhalin Island, but that record doubtless is referable to some oriental species.

Chlamys (Argopecten) subdola Hertlein
Plate 30, Figures 7, 8; Plate 35, Figures 2, 5, 9

Pecten (Plagioctenium) subdolus Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 1, p. 20, pl. 5, figs. 2, 4, 7, July 31, 1925. — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 443, 1926. "San Diego upper Pliocene of Pacific Beach, Calif." — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 94, 1944. Earlier records cited. — Hertlein and Grant, State Calif. Div. Mines, Bull. 170, Chapt. 2, p. 60, 1954. "San Diego formation."

Pecten (Aequipecten) purpuratus Lamarck variety *subdolus* Hertlein, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 211, pl. 5, fig. 1 (west of San Fernando Pass, Los Angeles Co.), 1931. "San Diego (Hertlein; Jordan and Hertlein; Hertlein and Grant)."

Pecten subdolus Hertlein, Hertlein and Grant, Calif. Jour. Min. Geol., Rept. State Mineral. 35, p. 69, 1939. Upper beds in Pliocene section at Pacific Beach. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, pp. 57, 59. Pacific Beach; Market Street one-tenth mile east of Euclid Avenue, San Diego, Pliocene.

Pecten (Argopecten) subdolus Hertlein, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 50, pl. 23, figs. a, b, 1968. Pacific Beach, Pliocene.

Type specimen. — No. 51, Stanford University, Department of Geology, Type Collection.

Type locality. — "Pacific Beach, San Diego, California." "San Diego, Pliocene."

Range. — Middle Pliocene of southern California and northern Lower California.

Occurrence in San Diego Fm. — C.A.S. 104, 105, 1132, 1182, 1183, 1401, 1413, 12145, 28880, 33334. L.A.M. 107, 122, 127, P.87: No. 58339. S.D. 5, 80, 365, 408. U.C.L.A. 300, 302, 2359.

Original description. — Shell of medium size, the valves moderately convex. Right valve ornamented by about 21 rounded, radiating ribs which become broader toward the ventral margin, the ribs separated by round-bottomed, narrower interspaces, the whole surface

ornamented by very fine radial striations and by concentric lines of growth; anterior and posterior margins sculptured only by concentric incremental lines; ventral margin rounded; ears unequal, the anterior with a well defined byssal notch, and sculpture of about six radiating riblets crossed by incremental lines; the posterior also sculptured by about six or seven slight radiating riblets crossed by lines of growth, a very slight notch present. Left valve more arched than right and somewhat one-sided in appearance, ornamented by about 21 rounded, radiating ribs separated by round-bottomed interspaces about as wide as the ribs, the whole surface finely longitudinally striate and crossed by concentric lines of growth; ears slightly concave, the posterior sculptured by very slight radiating riblets and concentric lines of growth, the anterior with a rounded notch, the surface sculptured by a few slight radiating riblets and by concentric growth lines, the ornamentation indistinct on weathered specimens. Altitude 50 mm, longitude 50 mm, diameter approximately 17 mm, apical angle in each valve approximately 105°. (Hertlein.)

Remarks. — This species occurs rather abundantly in the San Diego Formation, especially at Pacific Beach. One of the largest specimens from Loc. 1401 (CAS), south slope of Mount Soledad, is 64.2 mm long, 61 mm high, convexity (both valves together), 23 mm, length of hinge, approximately 32 mm, umbonal angle 105°.

The shell of *Chlamys subdola* resembles that of *C. callida*, with which it occurs, in outline and in general pattern of sculpture. It differs from the latter species in possessing a thinner shell, in the low rounded ribs, the presence of radial striae on the disk, and weaker sculpture on the ears.

Specimens of *Chlamys subdola* closely resemble some individuals of *Chlamys impostor* Hanna (394). We have examined a large series of *C. impostor* and it is evident that there is considerable variation in that species with respect to number of ribs (20 to 24), the elevation and degree of roundness of the ribs and in the umbonal angle. The largest specimens usually do not exceed 46 mm in altitude.

In comparison to *Chlamys impostor*, the shell of *Chlamys subdola* is thinner, it attains a greater size (altitude 50 to 61 mm), the ribs, of which there are usually fewer, are flatter and become broader toward the ventral margin, the ears are a little larger, and the ribs on the left valve are finer.

Grant and Gale (1931, p. 214) considered *Chlamys impostor* to be a variety of *Chlamys deserti* Conrad (395), whereas Woodring and Stewart (396) considered it to be a subspecies of *Chlamys circularis* Sowerby. Whatever the true relationship may be, there is a striking resemblance between some specimens of *Chlamys impostor* and those of *C. subdola*. However, the differences observed in series of the two lead us, at least for the present, to retain *C. subdola* as a species rather than a subspecies of *C. impostor*. Grant and Gale considered *Chlamys subdola* to be a variety of *C. purpurata* Lamarck. The differences between the two are obvious.

"*Aequipecten*" *revellei* Durham (Geol. Soc. Amer., Mem. 43, Pt. 2, p. 63, pl. 9, figs. 6, 9, 1950) described from strata of Pliocene age on Monserrate Island, in the Gulf of California, bears a resemblance to *C. subdola*, but differs in the more rounded outline and proportionally longer hinge line.

There is a general similarity in the outline and sculpture between *Chlamys subdola* and *C. eborea senescens* Dall (397) and the form *walkerensis* Tucker (398), which Tucker-Rowland later placed in the synonymy of *C. eboreus senescens* Dall. There are differences between the east and west coast species, such as in the shape of the posterior ear, and the relationship, if any, is unknown. Another species bearing a resemblance to *C. subdola* is *C. imitata* Weisbord (399) which was described from strata of Pliocene age in Venezuela.

In addition to its occurrence in the San Diego Formation, *Chlamys subdola* has been recorded by Grant and Gale (1931, p. 211) from "middle Pico" beds west of Fernando Pass in Los Angeles County, California. To the south it occurs abundantly at Cedros Island and it also occurs in Pliocene beds on the adjacent mainland of Lower California. Vokes (400) recorded it as occurring in beds of Pliocene age in the Santa Rosalía area on the east coast of Lower California but later authors have not reported it from the Gulf of California region.

SUBGENUS *LEPTOPECTEN* VERRILL

Leptopecten Verrill, Trans. Connecticut Acad. Arts Sci., Vol. 10, Pt. 1, p. 69, June, 1890. — Grau, Allan Hancock Pac. Exped., Vol. 23, p. 105, 1959. Type designation by monotypy.

Type species (by original designation). — "Type, *C. monotimeris* (Conrad)" [= *Pecten monotimeris* Conrad, Jour. Acad. Nat. Sci Philadelphia, Vol. 7, p. 238, pl. 18, fig. 10, 1837. "Inhabits with the preceding"] [which is, "Inhabits below the efflux of the tide near Sta. Diego and Sta. Barbara."] "The young occasionally found attached to *Fuci* by a slender byssus." Illustrated by I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 57, pl. 40, figs. 1 and 2, 1924. [These are not copies of Conrad's illustrations although stated to be so by Oldroyd.] See also Grau, 1959, p. 110, pl. 35, fig. 2.

Range. — Early Miocene to Recent. Recent from the intertidal zone to 219 meters (120 fathoms).

Description. — Shell thin, translucent, oblique, broadly rounded, with strong, rounded radial ridges or folds, like corrugations, which appear in reverse on the interior surface. The internal ribs are not angulated by a deposit of the shell, nor distinctly thickened. Margin with broad scallops. The exterior surface is covered with fine divergent camptonectes sculpture, both on the ribs and intervals. The ribs do not increase in number with age, but become broader and more flattened. Auricles large and broad, thin, corrugated. Byssal notch large and deep. Pectinidial teeth prominent. Hinge-plate thin and but little differentiated. Cardinal ridge thin and small, close to the ligament, crossed by fine incisions. The resilal pit is small, close to the ligament, crossed by fine incisions. The risilial pit is small, but projects beyond the thin hinge-plate in the left valve. (Verrill.)

This is a peculiar group, remarkable for its thin but strongly corrugated oblique shells, with fine camptonectes sculpture. (Verrill.)

Remarks. — About a dozen west American late Cenozoic species and subspecies are referable to *Leptopecten*. These small, thin, oblique shells differ sufficiently from those of *Aequipecten* and *Argopecten* to justify the

recognition of *Leptopecten* as a distinct subgenus.

The *Pecten andersoni* group which occurs in beds of Miocene age in western North America can be assigned to *Leptopecten.* Several species in the late Cenozoic of northern South America and in the Caribbean region also are referable to this subgenus. Among these are *Pecten atlanticola* Anderson and *P. macloskeyi* Anderson from Miocene beds in Colombia, and *P. bavayi* Dautzenberg and *Pecten linki* Dall living in the Caribbean.

Some of the species assigned to *Leptopecten* attain considerable size. Grau (written comm., March 1, 1965) mentioned that a large specimen of *C. (L.) monotimeris* from off an oil well platform off Summerland, California, is 49 mm long and 43 mm high.

Pecten (Leptopecten) praevalidus E. K. Jordan and Hertlein (401) described from beds of Pliocene age near Bahía Tórtolo (Turtle Bay), Lower California, attains a length of 50 mm, height 48 mm, and length of hinge line, 48 mm. In general appearance this species is remarkably similar to *Chlamys sacyi* Cossmann and Peyrot (402) described from beds of Burdigalian, Miocene age in France. The latter species is the type species of *Antipecten* Cossmann in Cossmann and Peyrot (403), which appears to differ from *Aequipecten* in the obliquity of the hinge line, larger ears, and in the unequal size of the ribs on the left valve.

Key to Species of *Leptopecten*

A. Ribs narrow, sharply topped; interspaces wider than the ribs . . . *bellilamellata*

B. Ribs squarish, flat topped; interspaces about as wide as the ribs . . . . . *latiaurata*

Chlamys (Leptopecten) bellilamellata Arnold
Plate 32, Figures 1, 2, 8

Pecten (Chlamys) bellilamellatus Arnold, U. S. G. S., Prof. Paper 47, p. 108, pl. 41, figs. 6, 6a, 7, 7a, 1906. — Arnold, in Eldridge and Arnold, U. S. G. S., Bull. 309, p. 252, pl. 40, fig. 14, April, 1907. "Pliocene, Pacific Beach, San Diego." — Arnold, Proc. U. S. Nat. Mus., Vol. 32, No. 1545, p. 546, pl. 50, fig. 14, June 15, 1907. "Pliocene, Pacific Beach, San Diego." — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 81, 1944. Records by Arnold cited.

Pecten (Aequipecten) bellilamellatus Arnold, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 205, 1931. "Pliocene: Pacific Beach, San Diego (Arnold)."

Type specimen. — No. 35, Stanford University, Department of Geology, Type Collection.

Type locality. — "Pliocene at Pacific Beach, San Diego, California.

Range. — Middle Pliocene at Pacific Beach, San Diego, California; Cedros Island, Bahía Tórtola (Turtle Bay) and Elephant Mesa, Lower California.

Occurrence in San Diego Fm. — C.A.S. 1400. S.D. 331.

Original Description. — Shell averaging about 18 millimeters in altitude, about as long as high, equivalve, both valves moderately convex, inequilateral; sides nearly straight; margins not serrate. Right valve with 15 or 16 prominent narrow, sharply convex-topped ribs with sloping sides; interspaces much wider than ribs, with narrow, flat bottoms; surface sculptured by numerous, regular, equidistant, thin, concentric, imbricating lamellae, which cut squarely across the bottoms of the interspaces, curve convexly toward the umbo on the sides of the ribs, and loop gracefully downward away from the umbo on the tops; hinge line equal to the length of the disk; ears equal in length; anterior ear convexly truncated, separated from the disk by a deep, sharply defined, byssal notch, and sculptured by fine, regular, incremental lamellae and five or six subequal radials; posterior ear acutely pointed, radially striate, and with incremental sculpture similar to but not quite as prominent as that of the anterior. Left valve similar to the right; anterior ear more prominently sculptured, both radially and concentrically, than the posterior. Dimensions. Alt. 18 mm, long. 18 mm, hinge line 18 mm, diameter 8 mm, umbonal angle 100°. (Arnold.)

"This species is characterized by its small size when adult, long hinge line, narrow, sharply topped ribs and beautifully curved incremental lamellae". (Arnold.)

Remarks. — The characters enumerated by Arnold easily serve to separate this species from *Chlamys (Leptopecten) latiaurata* Conrad and its subspecies *C. (L.)latiaurata delosi* Arnold. (404).

Two left valves from strata of Pliocene age at Pacific Beach in the collections of the California Academy of Sciences are referable to *Chlamys bellilamellata.* The larger one is 16.6 mm long, possesses 14 high, sharp-topped radial ribs which show traces of concentric imbrications. The other is a small valve 12.8 mm long which has but 13 narrow, sharp-topped, widely separated ribs which likewise show traces of concentric imbrications.

A small right valve from Loc. 331 (SD), from near the Mexican boundary is 14.6 mm long and 13.7 mm high, appears to be referable to the present species. There are about 13 sharply rounded ribs which are wider than the interspaces. The posterior ear is imperfect but the growth lines indicate an auricle similar to that of *C. (L.) bellilamellata.*

Three small valves and one large right valve 16.3 mm high and 16.5 mm long were collected in the upper portion of the Pliocene strata exposed at Pacific Beach.

Webb (405) reported the occurrence of this species in beds of Pleistocene age at Point Loma Peninsula, California, but we have not seen specimens.

Chlamys (Leptopecten) desultoria Weisbord (406), described from beds of Pliocene age in Venezuela, was compared by its author with *C. (L.) bellilamellata* from which it differs in possessing a radial thread in the interspaces.

Chlamys (Leptopecten) latiaurata Conrad
Plate 35, Figures 1, 3

Pecten latiauratus Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 238, pl. 18, fig. 9, 1837.

Pecten tunica Philippi, Abbild. u. Beschreib. Conchyl., Bd. 1, Heft 4, *Pecten,* p. 100 (2), pl. 1, fig. 3, January, 1844. "Habitat ad Insulas Sandwich." [Locality erroneous.]

Pecten latiauritus Conrad, Kobelt, Conchyl. -Cab. von

Martini und Chemnitz, Bd. 7, Abt. 2, p. 203, pl. 54, figs. 7, 8, 1888. "an der Westküste von Nordamerika, besonders an Californien." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 57 (under section *Leptopecten*), pl. 22, fig. 2, 1924. "Monterey, California, to the Gulf of California," Recent. [Reproduction of Conrad's original figure of *P. latiauratus.*]

Pecten (Chlamys) latiauritus Conrad, Arnold, U. S. G. S., Prof. Paper 47, p. 115, pl. 46, figs. 2, 2a, 3, 3a, 1906. Pliocene to Recent.

Chlamys (Leptopecten) latiaurata Conrad, Grau, Allan Hancock Pac. Exped., Vol. 23, p. 107, pl. 35, fig. 1, 1959. Earlier records cited.

Type specimen. — Two syntypes in British Museum (Natural History), Nos. 55.3.14.53 and 61.5.20.89 (A. M. Keen, Veliger, Vol. 8, No. 3, p. 169, 1966).

Type locality. — "Inhabits below the efflux of the tide near Sta. Diego and Sta. Barbara." [California.] "Type locality: San Diego, California" (Grau).

Range. — Middle Pliocene to Recent. Recent from Point Reyes, California, to Cape San Lucas, Lower California, Mexico. Also Guadalupe Island. Reported from 1 foot (minus tide) to 229 meters (125 fathoms). Found attached to rocks or pilings in shallow water; in deeper water on rock, shale, gravel, or sand bottoms, often attached to calcareous algae. (Grau.)

Occurrence in San Diego Fm. — S.D. 331. U.C.L.A. 312.

Original description. — Shell inequilateral, thin, compressed; ribs fourteen, flattened on the back, slightly sulcated; interstices transversely striated; ears very wide, unequal, both acutely angulated at the extremity; colour reddish brown and white, variegated or spotted. (Conrad.)

A series of specimens reveals that the number of ribs may vary from 12 to 16. Some of these may be faintly medially sulcated. A faint intercalary riblet may be present in the interspaces especially on large specimens.

Remarks. — Three right and one very small left valve of this species are present in the collection from Loc. 312 (UCLA). The largest specimen, a right valve, is 16.9 mm long and 17.5 mm high. One small right valve 14.6 mm long was collected at Loc. 331 (SD). A large Recent specimen of this species in the collections of the California Academy of Sciences collected by H. N. Lowe at Long Beach, California, is 33.8 mm long, 31 mm high, convexity (both valves together), 11.9 mm, length of hinge, 28 mm.

This is the first record of the occurrence of *Chlamys (Leptopecten) latiaurata* in the San Diego Formation. Woodring (407) questioned Arnold's record of the occurrence of this species in the Third Street tunnel in Los Angeles. However, it has been recorded from beds of Pliocene age elsewhere. Arnold (408) reported it from the "lowest Merced horizon developed in the Santa Cruz quadrangle" and E. K. Jordan and Hertlein (409) recorded it from beds of Pliocene age at Cedros Island and at Bahía Tórtolo (Turtle Bay), Lower California.

Chlamys (Leptopecten) latiaurata differs from *C. (L.) monotimeris* Conrad in the squarish ribs rather than rounded undulations of the shell.

A species described from the Gulf of California, *Aequipecten (Leptopecten) camerella* Berry (410), is said to resemble *C. (L.) latiauratas* but "differing chiefly in its smaller size, plumper more rounded form, smooth intervals between the radii of the disk, and lighter coloring."

Ferreira (411) reported a species under the name of "*Chlamys (Leptopecten)* cf. *latiaurata*" from beds of early Miocene age in Brazil. Judging solely from the illustrations, the Brazilian form resembles some species of *Leptopecten* described from the late Cenozoic of the Caribbean region more closely than it does the west American species.

Aequipecten (Leptopecten) cracens Olsson (412), described from strata of Miocene age in Ecuador, is sculptured with 17 coarsely noded radial ribs.

The present species, *C. (L.) latiaurata*, commonly known as "kelp-pecten", occurs at many places along the coast of southern California attached by its byssus to vegetable growths, pilings, or rocks. It occurs in shallow water but it has been taken at a depth of 229 meters (125 fathoms). Coe (413) discussed the growth and reproduction of this species. It reaches maturity in about 9 to 12 months and in that period of time attains a length of about 32 mm.

Formerly it flourished in the still, warm waters of Mission Bay (414), San Diego Co., where it lived attached to *Zostera.*

SUBGENUS *SWIFTOPECTEN* HERTLEIN

Swiftopecten Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 21, No. 25, p. 319, September 26, 1935. "the type of which is *P. swiftii* Bernardi." — Hertlein, Nautilus, Vol. 50, No. 1, p. 24, July 14, 1936. "Type: *Pecten swiftii* Bernardi."

Type species (by original designation.) — *Pecten swiftii* Bernardi [Journ. de Conchyl., Vol. 7, p. 90, pl. 1, fig. 1; pl. 2, fig. 1, July, 1858. "Hab. la baie Nicolas, dans la Manche de Tartarie." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, pl. 10, figs. 1a, 1b, 1931. (Reproduction of original figures of Bernardi.) — Masuda, Trans. Proc. Palaeo. Soc. Japan, N. S., No. 34, pp. 86-96, pl. 9, 1959.]

Range. — Late Miocene (Stanton) to middle Pliocene in California; mid-Miocene to Pleistocene in Alaska; early Miocene to Recent in Japan. Recent in from 1 to 143 meters (1 to 78 fathoms).

Description. — Shell of medium size, higher than long, nearly equivalve, ears well developed, the right the larger and with a deep byssal sinus and a ctenolium; right valve sculptured with 4 or 5, or occasionally more, large, coarse, rounded radial ribs (paired in some species), formed by corrugations of the shell, the left valve similar but with smaller ribs; valves usually with concentric undulations which form node-like areas on the ribs of the left valve; entire surface of valves and ears ornamented with rather coarse radial riblets, and the exterior surface superficially microscopically tessellated; hinge of right valve with an elevated ridge on each side of the ligamentary pit and fitting into two corresponding grooves in the hinge of the left valve; margin reflects the major exterior sculpture.

Remarks. — The members of *Swiftopecten* all have valves of nearly equal convexity, the left more so, and are chlamydoid in shape. The few coarse ribs where crossed by concentric undulations are thickened and give rise to node-like ornamentation. The character of the hinge with the two ridges, one on each side of the ligamentary

pit on the right valve and corresponding depressions on the left, bring to mind the observations of Beyrich and Futterer concerning correlation of the ribbing and the hinge of *Neithea*. Futterer (415) stated that "Hand in Hand mit dem Vorhandsein dieser 2 Zähne geht die ausbildung eines 6-strahligen Baues in der Schalensculptur."

Concentric undulations somewhat similar to those on *Swiftopecten* occasionally occur on some species of *Lyropecten* such as those on *Chlamys (Lyropecten) crassicardo* and on *C. (L.) estrellana* and those on the Floridan *C. condylomata* Dall, an east American Miocene species. Node-like sculpture somewhat similar to that on *Swiftopecten* also is present on species of *Nodipecten* such as on *C. (N.) nodosa* Linnaeus, *C. (N.) subnodosa* Sowerby and *C. (N.) nodulifera* Sowerby.

Typical members of *Swiftopecten* made their first appearance in Japan in early Miocene and in western North America in strata of middle Miocene age in southeastern Alaska. In California this group of scallops first appear in beds of late Miocene age (Castaic Formation). Individuals occur abundantly in beds of middle Pliocene age in Lituya Bay in southeastern Alaska, in California from Crescent City to San Diego, and in Lower California on Pliocene terraces east of San Quintín, and at Bahía Tórtolo (Turtle Bay). A species of Pleistocene age, *C. (S.) kindlei* Dall, occurs in terrace deposits east of Nome, Alaska.

A species known to occur in beds of Miocene age in California, believed by some authors to bear relationship to members of the *Swiftopecten* group is the form described by Arnold as *Pecten (Chlamys) hamlini* (416). The type, a right valve, is, as mentioned by Arnold, a distorted specimen. We have examined a cast of the type specimen. It possesses 4 broad ribs each of which are radially grooved forming 5 radiating ridges. This rare species may be related to the *Swiftopecten* group or it may be referable to some other group with radially grooved ribs. Species such as *Pecten praevasseli* de Böckh and Richardson (417) in Douglas, a Persian species, have somewhat similar ribbing though no real relationship to such species is here suggested. The relationship, if any, of *P. hamlini* with other Californian species is not known at the present time.

The specimen of late Miocene age from California illustrated by Adegoke (Veliger, Vol. 9, No. 3, pp. 337-339, pl. 47, figs. 1 and 2, 1967) under the name of "*Swiftopecten* spec.", appears to be a juvenile *Lyropecten*.

Several species and subspecies of *Swiftopecten* have been described from Japan, Kamtschatka, and western North America. This group had its origin in the northern Pacific where the greatest number of extinct forms have been described and where the single Recent species, *C. (S.) swiftii*, has been recorded as occurring from late early Miocene to Recent in Japan.

Matsumoto suggested that the Miocene species described by him as *Pecten natoriensis* (418) is an ancestral form of *C. (S.) cosibensis* Yokoyama. Hatai and Nisiyama (419) in 1935 discussed the relationship of *C. (S.) cosibensis* Yokoyama, *C. (S.) heteroglypta* Yokoyama and *C. (S.) swiftii*. They believed, correctly we think, that the two former forms are distinct from *C. swiftii* and its American relatives with whose synonymy they were involved by Grant and Gale. Later Hatai and Nisiyama (420) called attention to the similarity of *C. natoriensis* and the form described by Arnold as *Pecten (Chlamys) nutteri*. The shells of *C. (S.) cosibensis* and *C. (S.) heteroglypta*, especially during their earlier geological occurrences, are smaller than *C. (S.) swiftii*. Furthermore they have more ribs which are more nearly equal in size than those of *C. (S.) swiftii*. These facts together with the observation of Hatai and Nisiyama that in their early stages these species reveal a tendency to be more circular in outline, all point toward a specialized development from a chlamyd form. More recently Masuda (1962) referred *C. cosibensis* and *C. heteroglypta* to *Chlamys s. s.*, an assignment not convincing to us.

Hatai and Masuda described a genus, *Nanaochlamys* (421), based upon *Pecten notoensis* Yokoyama. In the synonymy of this species they placed the forms named by Matsumoto as *Pecten natoriensis*, *P. n. subovalis*, and *P. n. inequilateralis*. The shell characters of their new new genus were compared with those of *Mesopeplum* Iredale and *Scaeochlamys* Iredale. Later Masuda (1962, p. 196) stated that *Nanaochlamys* is closely related to *Swiftopecten* but differing in "its orbicular symmetrical shell, surface sculpture, shape of auricles and indistinct ctenolium." He gave the range of *Nanaochlamys* as late Oligocene to Miocene.

Some authors have considered the type species of *Nanaochlamys* to be an ancestral member of the *Swiftopecten* group. If subsequent studies confirm this relationship, then *Nanaochlamys* would have little significance as a supraspecific taxonomic unit. According to MacNeil (U. S. G. S., Prof. Paper 553, p. 11, 1967), the left valve of *N. notoensis* is flat or slightly concave in the juvenile stage and this he believes is evidence opposed to close relationship to *Swiftopecten*.

The line of development indicated by members of *Swiftopecten* is quite distinct from that of *Decatopecten*, *Manupecten* and *Semipallium*, with which, at times, members of *Swiftopecten* have been placed. These subgenera include shells which are sculptured with a few coarse radially striated ribs.

Decatopecten Rüppel in Sowerby (422), type *Pecten plica* Linnaeus, includes shells of medium small size of which the right valve is a little more convex than the left, the hinge is short, byssal sinus very slight, and the hinge armature consists of perpendicular tooth-like plaits.

This subgenus occurs from Pliocene to Recent in the north Pacific, East Indies, and Red Sea region, in the post-Pliocene of east Africa and Recent from Japan to the Red Sea.

Anguipecten Dall, Bartsch, and Rehder (423), has hinge characters similar to those of *Decatopecten*, but the hinge line is shorter and the external sculpture consists of many nearly equal, rounded, radial ribs. It is represented in the Miocene of New Caledonia and Recent in Hawaii, Japan and the western Pacific.

Manupecten Monterosato (424), type *Pecten pesfelis* Linnaeus, occurs from mid-Miocene to Recent in the Mediterranean region and in Miocene and Pliocene strata in the Red Sea region. It lacks concentric undulations of the shell as well as a low ridge on each side of the ligamental pit of the right valve such as occur on *Swiftopecten*. In the character of the hinge and in some details of the sculpture *Manupecten* bears a closer resemblance to *Chlamys* than it does to *Swiftopecten*. *Felipes* Locard in Carus (425), is a synonym of *Manupecten* as it has the same type species.

Semipallium Jousseaume (426), type *Pecten tigris* Lamarck, bears a close resemblance to *Manupecten*, but in the former group the left valve is generally consistently flatter than the right one. This character as well as the lack of concentric undulations on the left valve and the smaller size, easily serve to separate the members of this group from those of *Swiftopecten*. *Semipallium* occurs in the northern and western Pacific and Indian Ocean region. It is known to range from Miocene to Recent.

It is obvious that *Swiftopecten* is not closely allied to these groups nor to others which resemble it only in that they possess a few coarse radial ribs, such as *Mesopeplum* Iredale (427), *Notochlamys* Cotton (428), *Anatipopecten* Hertlein (429), and *Stralopecten* Rowland (430).

Chlamys (Swiftopecten) parmeleei Dall
Plate 31, Figure 5; Plate 37, Figures 1-10
Text Figure 10

Pecten (Chlamys) parmeleei Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 708, pl. 37, figs. 14, 14a, April, 1898. "Pliocene of San Diego, California; Parmelee." — Schuchert, Dall, et al., U. S. Nat. Mus., Bull. 53, Pt. 1, p. 490, 1905. Original locality cited. — Arnold, U. S. G. S., Prof. Paper 47, pp. 28, 100, 119, pl. 41, figs. 1, 1a (copies of original figures), "San Diego formation (Pliocene, Pacific Beach, San Diego County, Cal.)", figs. 5, 5a ("Pliocene, Crescent City, Del Norte County, Cal."), 1906. — Arnold, in Eldridge, U. S. G. S., Bull. 309, p. 244, pl. 36, fig. 7, 1907. Type specimen illustrated and type locality cited. Also Pliocene of Puente Hills, southern California. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 92, 1944. Earlier records cited.

Pecten parmeleei Dall, Dall in Diller, U. S. G. S., Bull. 196, 1902. P. 32, wharf at Crescent City, p. 39, "same age as that at San Diego." Pliocene. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919 (as *Pecten parmaleei*). "San Diego," Pliocene. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 85, 1929. "Pliocene" "San Diego fauna." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 172. "Pliocene of San Diego."

Pecten (Pallium) swiftii Bernardi form *parmeleei* Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 900, pl. 10, figs. 2, 5 (Holser Canyon, Los Angeles Co., Calif., Pliocene), 1931.

Pecten (Swiftopecten) parmeleei Dall, Hertlein and Grant, Calif. Jour. Min. Geol., Rept. 35, Calif. State Mineral., p. 69, 1939. "south slope of Soledad Mountain the San Diego formation." — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 56, "Pliocene strata at Pacific Beach," p. 57, "south sloping spurs of Mount Soledad," p. 59, "near the Mexican Boundary about three-quarters of a mile from the sea," 1944. — Hertlein and Grant, Calif. State Div. Min., Bull. 170, Chapter II, p. 60, 1954. "San Diego formation." "middle Pliocene or early upper Pliocene age."

Chlamys parmeleei Dall, Stewart, in Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, p. 91, 1941. Pliocene at San Diego. — Woodring in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, pp. 65, 83, 103 (Jacalitos and upper part of San Joaquin), 104 (Pacific Beach and inland, San Diego, Calif., Pliocene), 106, pl. 16, fig. 20 (Fugler Point, Santa Maria district, Calif., Pliocene), 1950. — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. "San Diego formation." Also Niguel Formation and others.

Chlamys etchegoini parmeleei Dall, Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, 1941. Pacific Beach, San Diego.

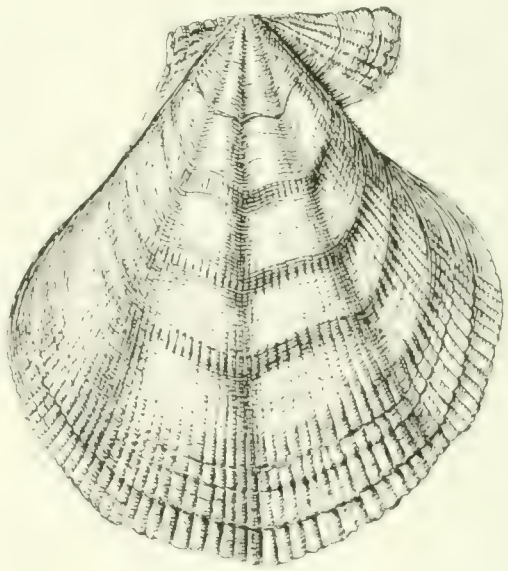
Type specimen. —Holotype, No. 154,479 United States National Museum.

Type locality. — "Pliocene of San Diego, California."

Range. — Late Miocene (Stanton); middle Pliocene, from southeastern Alaska to Bahía Tórtolo (Turtle Bay), Lower California.

Occurrence in San Diego Fm. — C.A.S. 957, 1401, 1413, 12147. L.A.M. 107, 116, 305, 305A, 318. Strata exposed in 1600 block, Larwood drive and Veya Court, Encanto. S.D. 38, 80, 408, 2916, 4735. Redwood Street and Swift Canyon. U.C. A-8333. U.C.L.A. 294.

Original description. — This species is close to *P. Swiftii* Bernhardi of Japan (J. de Conchyl., vii., plates 1 and 2, 1858) but smaller, and differs by the smooth top surface of the ribs, which in *P. Swiftii* are more or less striated or coarsely threaded, and by the not alternated radial riblets on the right posterior ear; also, especially, by the profuse coalescent microscopically checkered squamation, which makes a complete external coating to the valve. Alt. 45, lat. 38 mm. (Dall.)



Text Fig. 10. *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Cat. No. 4735, San Diego Society of Natural History), right valve, from India and Spruce streets, San Diego; Pliocene. Length 64.8 mm. (Drawn by E. H. Quayle.)

Remarks. — About 150 specimens of *Chlamys (Swiftopecten) parmeleei* are present in collections observed by us from the San Diego Formation from the south slope of Mount Soledad, Pacific Beach, in San Diego, and near the Mexican boundary. Most of these are single

valves, the left more convex than the right, many in excellent state of preservation. The largest specimen in the collections of the San Diego Society of Natural History is a right valve, Cat. No. 2916 (SD), from Reynard Way (the anterior dorsal portion imperfect), 73.5 mm long, 75 mm high, convexity 18 mm. Another well preserved right valve, Cat. No. 4735 (SD), from India Street near Spruce Street in San Diego, is 65 mm long, 71.6 mm high, convexity 13 mm.

A fine series comprising most of the specimens of *C. parmeleei* studied by us was collected by G. P. Kanakoff at Locs. 305 and 305A (LAM) near the Mexican boundary. Individuals of various sizes, from 4 to 79 mm high, were present. Some attain a height of 32 mm with only a trace of undulation of the shell. Some have three, others as many as five, constrictions in the shell. These undulations, where they cross the ribs, lend a nodose appearance to the ribs.

The ribs are large, convex and consist of folds in the shell, those of the right valve corresponding to the interspaces of the left. There are four broad ribs on the right valve and often in addition a narrow, minor one near the anterior and posterior margins. The ribs on this valve are separated by narrower interspaces than those on the left. There are five ribs on the left valve which is more convex than the right. The ribs and interspaces of both valves are sculptured with nearly equal, coarse, radial threads. The anterior ears are much larger than the posterior ones and are sculptured with 5 to 9 riblets, those on the left posterior ear are fine and nearly equal in size.

Chlamys parmeleei described by Dall in 1898 was the first representative of the *Swiftopecten* group to be described from western North America. West American species which generally have been considered to be relatives of *C. (S.) parmeleei* were originally described in the following chronological order: *Pecten etchegoini* Anderson (431), *Pecten (Chlamys) hamlini* Arnold (432), *Pecten (Chlamys) nutteri* Arnold (433), *Pecten (Chlamys) wattsi* Arnold (434), *Pecten (Chlamys) wattsi* var. *morani* Arnold (435), and *Pecten (Chlamys) kindlei* Dall (436). *Chlamys (Swiftopecten) donmilleri* MacNeil (437) was described recently from the Yakataga Formation of probable middle Miocene age in southeastern Alaska. The illustrations closely resemble some specimens of *C. (S.) parmeleei* but the Alaskan species was said to be comparable to the species described as *Pecten (Swiftopecten) otutumiensis* Nomura and Hatai from the Otsutsumi Formation of middle Miocene age in Japan.

There is considerable variation in the size and sculpture of the various forms of *Swiftopecten* of Pliocene age in California. Arnold (438) later recognized the identity of the form described as "*Pecten (Chlamys) wattsi* var. *morani*" with *Pecten etchegoini*. He pointed out that *C. (S.) etchegoini* is characterized by a lack of concentric constrictions whereas such constrictions were described as common on typical *C. (S.) wattsi*. We have examined fragments of the type specimen of *C. (S.) etchegoini* which were recovered by F. M. Anderson from among the ashes caused by fire resulting from the earthquake in 1906. These fragments are the remains of a right valve which is No. 55 in the type series in the department of Geology, California Academy of Sciences. The largest fragment is 59 mm high and 42 mm long. It agrees exactly with the corresponding portion of the original illustration of that species. The specimen shows no concentric undulations and it is quite deeply radially grooved. The latter character, however, may be accentuated due to erosion and fire.

Nomland (439) illustrated a number of specimens from the Etchegoin Pliocene of the San Joaquin Valley and concluded that the species described as *Pecten wattsi* and *P. nutteri* both intergrade with *C. etchegoini*.

Grant and Gale, 1931, placed *C. (S.) parmeleei* in the synonymy of *C. (S.) swiftii* and *C. (S.) etchegoini*, *nutteri* and *kindlei* as varieties of *C. (S.) swiftii*. They believed that *C. (S.) etchegoini* was a stunted form bearing very coarse striations on the ribs.

Stewart in 1941 studied fossil specimens from San Joaquin Valley and concluded (correctly, we believe) that west American forms of this group are probably more closely related to *C. (S.) parmeleei* than to *C. (S.) swiftii* although he recognized their similarity to the Recent Japanese species. He believed that *C. (S.) parmeleei* with prominent undulations is probably the same species as *C. (S.) wattsi* Arnold, differing in this character from *C. (S.) etchegoini*.

Woodring (in Woodring and Bramlette, 1950), recently inferred from a study of specimens from Pliocene beds in the Santa Maria district, that there were two recognizable forms in that area, *C. (S.) parmeleei* in the Cebada Member of the Careaga Sandstone and *C. (S.) parmeleei etchegoini* in the Foxen Mudstone.

Stewart mentioned that the ears of *C. (S.) etchegoini*, especially on the left valve, are set off by furrows from the disk, differing in this respect from *C. (S.) swiftii*. Woodring (1950) also recognized this difference and mentioned that the dorsal umbonal portion of large specimens of *C. (S.) parmeleei* is more inflated than the corresponding portion on *C. (S.) swiftii*. However, these characters vary in a series of specimens.

Pecten etchegoini Anderson was reported by B. L. Clark (440) from Pliocene terraces east of San Quintín Bay, Lower California. Recently Edwin C. Allison (441) collected a few right valves, the largest, 80 mm in altitude, from a terrace at the top of the mesa east of San Quintín Bay. The southernmost occurrence of *Swiftopecten* reported from the west coast of North America, is at Bahía Tórtolo (Turtle Bay), Lower California, where Allison collected a left valve at Loc. B-3019 (UC). The right valves from east of San Quintín almost lack concentric undulations and are deeply grooved. Based upon this character, these fossils could well be identified with *C. (S.) etchegoini*. A portion of a valve similar to these was collected by Henry Hemphill at Pacific Beach, differing only in that it is gently undulated. Traces of microscopic squamation, believed by Dall to be characteristic of *C. (S.) parmeleei*, also are present on the valves from Lower California. Such ornamentation, however, also is present on specimens of *C. (S.) swiftii*. The specimens illustrated by Slodkewitsch (442) as representing *C. (S.) etchegoini* from strata of Pliocene age in Kamtschatka, all show concentric undulations and are probably referable to some other species.

We have not made an intensive study of the members of this group described from the San Joaquin Valley, but *C. (S.) parmeleei* is the earliest name applied to a member of this group in North America and any subspecies or variety of later date must assume a subspecific

or varietal status of *C. (S.) parmeleei*, a fact not recognized by some of the earlier authors. We consider *C. (S.) parmeleei* to be a valid species (including *C. wattsi* as a synonym) with *C. (S.) etchegoini* (including *C. morani* as a synonym) as a subspecies and *C. (S.) nutteri* a separate species.

The Alaskan form *C. (S.) kindlei*, said to be characterized by its large size and low convexity, resembles *C. (S.) swiftii* in general characters and especially in the shape and size of the posterior ears. We have examined single valves from Loc. 483 (CAS), from a depth of seventy feet on a terrace near Nome, Alaska.

A comparison of large specimens of *Chlamys (Swiftopecten) parmeleei* with *C. (S.) swiftii* from Japan reveals that on *C. (S.) parmeleei* and its subspecies the left posterior ear is generally sculptured with finer more nearly equal riblets. The radial threads on both valves of the Japanese shell tend to bifurcate toward the ventral margin whereas those on *C. (S.) parmeleei* only rarely show this feature. Furthermore the west American forms do not reach the size of *C. (S.) swiftii* which attains a height of at least 108 mm.

There is variation in the development of undulations of the valves in a series of *C. (S.) swiftii* but apparently all show in some degree undulations or constrictions in the growth of the shell. Masuda (1959), in discussing the variation of the shells of *C. (S.) swiftii*, mentioned that the valves are less convex and the constrictions less developed on individuals from northern Asiatic waters. He suggested that these features may be influenced by the smaller range in the annual water temperature in northern waters because greater variation occurs in shells which occur in more southern waters where there is greater range in the annual water temperature.

In addition to the occurrence of *Chlamys parmeleei* in the San Diego Formation, it has been reported from the Yakataga beds in southeastern Alaska; Crescent City, northern California; Purisima Formation (443); Jacalitos Formation and San Joaquin Formation in San Joaquin Valley; Cebada Member of the Careaga Sandstone, Santa Maria district; eastern Ventura basin; Simi Valley; in Elsmere, Holser and Temescal canyons and in the Puente Hills, southern California. Stanton (Jour. Paleo., Vol. 40, No. 1, pp. 23, 27, 1966) reported this species from the Castaic Formation of late Miocene age. We have not seen specimens from that area.

Chlamys (Swiftopecten) swiftii, a relative of *C. (S.) parmeleei*, lives in the waters about Japan, on the Pacific Ocean side from 38° to 51°north Latitude and on the Japan Sea side as far south as 35°, at depths of 1 to 143 meters (1 to 78 fathoms).

SUBGENUS *LYROPECTEN* CONRAD

Lyropecten Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 14, p. 291, August 1, 1862. Species cited: "*Lyropectin (Pallium) estrellanus*, C., Pacific R. R. Rept., 1855, vi. pl. 3, f. 15."; "*Pallium estrellanum*, in Pacific Railroad Reports, vol. vii. 191, ... I propose to name it *Volaeformis*"; and "*L. crassicardo.*" — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, pp. 695, 701, 1898. "Type *P. estrellanus* Conr." — Arnold, U. S. G. S., Prof. Paper 47, p. 49, 1906. "Type *P. estrellanus* Conrad." — Woodring, U. S. G. S., Prof. Paper 190, p. 34, 1938. Type as designated by Dall, 1898.

Lyropectin Conrad (err.), Proc. Acad. Nat. Sci. Philadelphia, Vol. 14, p. 291, 1862.

Liropecten Conrad (emend. or err.), Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 105, 1869.

Not *Lyriopecten* Hall in A. S. Miller, 1877. Type: *Avicula orbiculata* Hall. Middle Devonian.

Type species (designated by Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, pp. 695, 701, 1898). — "Type *P. estrellanus* Conrad." [Described as *Pallium estrellanum* Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, No. 6, p. 313, December, 1856 [apparently issued early in 1857]. "Locality. Estrella valley, Cal." — Conrad, Pac. Railroad Expl., Vol. 6, Pt. 2, p. 71, pl. 3, fig. 15, 1856 (1857). "Estrella Valley, Cal." Lectotype designated by Woodring (1938, p. 33) as the specimen illustrated by Arnold (U. S. G. S., Prof. Paper 47, pl. 20, fig. 1, 1906) which was from "Santa Margarita formation (upper Miocene), Estrella valley, San Luis Obispo County, Cal." This same specimen was designated as neoholotype by Tucker-Rowland (Mém. Mus. Roy. Hist. Nat. Belgique, Deuxiéme Sér., Fasc. 13, p. 4, July 31, 1938).]

Range. — Early Miocene (Vaqueros Formation) to middle Pliocene.

Description. — Shell large, thick, valves usually nearly equally inflated, sometimes undulated in the vicinity of the umbos, sometimes strongly constricted at various stages of growth; ears nearly equal in size, a byssal notch present under right anterior ear; ribs large and undivided; entire shell covered with radial striae and fine concentric imbrications; hinge with large coarse cardinal crura or teeth.

Remarks. — *Lyropecten* was represented during late Tertiary time in western North America by about a dozen species and subspecies. Various authors have speculated on the origin of this group with varying conclusions. J. P. Smith (444) suggested a Caribbean origin for the group. Woodring (1938, p. 35) stated that this subgenus may occur in beds correlated with the Chipola Formation in Florida of early Miocene age and that it is definitely represented in the Calvert Formation in Maryland, in beds of approximately middle Miocene age, but that no species of *Lyropecten* are known in the Tertiary strata in the Caribbean region or in Central America. Olsson (445) described one species referred to *Lyropecten* from beds of late Miocene age in Peru, but we have not seen specimens. An interesting occurrence is that of a large broad-ribbed species cited as *Pecten (Lyropecten) magnolia* Conrad by Haas (446), but probably referable to the *Pecten jeffersonius* group, from beds of Miocene age at Carballo, Costa Rica.

The assignment of large east American late Tertiary species to *Lyropecten* has been an accepted practice by Dall, Gardner, Mansfield, Tucker-Rowland, Woodring, Grant and Gale, and others. Certainly some of the species from the east and west American Tertiary beds are remarkably similar. However, most of the east American species lack the coarse hinge teeth which are so prominent on *Lyropecten*. Dollfus (447) long ago pointed out the similarity between some of the west American and Tertiary European species. Later Grant and Gale, and Clark and Durham (448), mentioned some of the same "analogous" species.

It is an interesting fact that Conrad who was familiar with east American species stated concerning *Lyropecten*, "This genus is peculiar to the Miocene of the Pacific slope . . ."

Most of the European authors while recognizing the similarity of some of the large European species with some of the American Tertiary fossils have hesitated to assign their species to *Lyropecten*. Roger (1939, p. 246), who made a careful study of the European Cenozoic Pectinidae, considered *Pecten madisonius* Conrad to be a *Chlamys* distinct from *Lyropecten*. North (449) who studied the supraspecific units of the Pectinidae also stated that in his opinion the large east American species are large chlamyds unrelated to *Lyropecten*. These two authors, who are familiar with European species, restrict the usage of *Lyropecten* solely to west American late Tertiary species.

The only east American species which we have seen whose sculpture and hinge bear a resemblance to those of *Lyropecten* was described as *Pecten (Nodipecten) condylomatus* Dall from the early Miocene of Florida. Some slightly nodose specimens of this species are very similar to the species described as *Pecten (Lyropecten) pretiosus* Hertlein from strata of early Miocene age in Baja California. A series of specimens of *C. condylomatus* was collected by T. F. Stipp from the type San Fernando Formation (of Dumble, 1915) in Tamaulipas, Mexico. Some of these, 70 mm high (considerably larger than the type specimen) and nearly devoid of nodes, closely resemble some specimens of *C. (L.) miguelensis submiguelensis* Loel and Corey of comparable size from the early Miocene of California.

The similarity of *Pecten magnolia* Conrad and *P. jeffersonianus* Conrad to European species of *Macrochlamis* Sacco (450) (*Gigantopecten* Rovereto, 1898; *Grandipecten* Cossmann and Peyrot, 1914), type, *Pecten latissimus* Brocchi, has been mentioned by several authors. It seems possible that they may be of related stock because there is reason to believe that conditions existed which were favorable to migration of marine organisms between the Mediterranean and the western Atlantic. This hypothesis is strengthened by the presence of another Tethyian subgenus, *Amussiopecten*, which occurs in mid-Tertiary beds in the Caribbean (451) region and which is represented in the west American early Miocene strata by *Pecten vanvlecki* Arnold. *Amussiopecten* also is present in strata of Miocene age in the East Indies and in beds of Miocene and of Pliocene age in Japan, but there is no evidence to indicate that this subgenus reached western North America by way of the North Pacific. *Lyropecten* is not known to occur in that region.

Nodipecten Dall (452) with the type *Pecten nodosus* Linnaeus, includes a group of species somewhat similar in general characters to those of *Lyropecten*. They have broad, usually undivided ribs, rather few in number, ornamented with hollow nodes, and the entire valves are sculptured with fine or rather coarse radial threads. The posterior ear is often smaller than the anterior one; hinge characters similar to those of *Lyropecten*.

Some species of Pectinidae belonging to quite different groups bear nodes on their valves, especially on the ribs where valves are constricted or undulated. Two such species in the later Tertiary beds of Europe, *P. melii* Ugolini and *P. sardoa* Ugolini, were referred to the "Groupe de *Chlamys nodosa*" by Roger (453). He placed (1939, p. 37) *Pecten nodosiformis* de Serres in the *Chlamys tournali* group which he indicated was referable to "*Macrochlamys*" of Sacco. Eames and Cox (454) placed that species in the subgenus *Gigantopecten* under the genus *Pecten*. Roger considered *Nodipecten* to differ from *Gigantopecten* [= *Macrochlamis* Sacco] in the smaller apical angle, the more unequal ears and better developed byssal sinus. He stated that only the presence of nodes creates a similar appearance between the two groups. The *Nodipecten* group is known to range from Miocene to Recent in the Caribbean region and from Pliocene to Recent in the west American Cenozoic.

Some of the shell characters mentioned by authors upon which *Lyropecten*, *Macrochlamis*, and *Nodipecten* have been separated are the difference in the convexity of the two valves, the presence or lack of a ctenolium (pectinidial teeth), the apical angle, and presence or absence of nodes. All these shell characters are variable and occur in various species assigned to these different groups.

The type species of *Lyropecten* is a west American Miocene species and this group is well developed in that region from early Miocene to middle Pliocene. *Lyropecten*, throughout its history, appears to have been restricted to the eastern Pacific. The latest species, *C. (L.) cerrosensis*, occurs in strata of Pliocene age in southern California and in Lower California. Grant and Gale (455) assigned *Pecten magnificus* Sowerby, a Recent tropical west American species, to *Lyropecten*, but it is more properly placed in *Nodipecten*.

The recent species of *Nodipecten* are inhabitants of tropical and subtropical waters. *Chlamys (Nodipecten) subnodosus* var. *intermedius* Conrad, ranges north at least to Los Angeles Bay in the Gulf of California (perhaps farther) and to Scammon Lagoon on the west coast of Lower California (456). *Lyropecten* also appears to have been an inhabitant of waters, perhaps subtropical rather than tropical.

Athlopecten Marwick (457), type *Pecten athleta* Zittel, from beds of early Miocene or late Oligocene age in New Zealand, includes species with large coarse shells with undivided ribs. There is some resemblance to *Lyropecten* but any direct relationship has not been demonstrated. *Pecten athleta* bears a resemblance to *Pecten simpsoni* Philippi (458), from the middle Tertiary of Chile, but there is no evidence that either species is referable to *Lyropecten*.

Vertipecten Grant and Gale (1931, p. 188), type, *Pecten nevadanus* Conrad, has a large thick shell with irregular, often spiny ribs, and the hinge lacks teeth such as are present on *Lyropecten*. They compared *Vertipecten* to *Phialopecten* Marwick. We have examined specimens of the type species of *Phialopecten*, *P. triphooki* Zittel, which we received from Dr. C. A. Fleming, and any postulated relationship with *Vertipecten* appears purely speculative.

Sectipecten Marwick with broad ribs, late Miocene to middle Pliocene in New Zealand, is believed by Boreham (459) to have been derived from the *Mesopeplum* group.

Chlamys (Lyropecten) cerrosensis Gabb
Plate 34, Figures 1-4; Plate 36, Figure 7

Pecten cerrosensis Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 32, pl. 9, figs. 55, 55a, 1869. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 173, 1912. "San Diego-Purisima." "Pliocene." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego." Pliocene. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, pp. 84, 85, 1929. "San Diego Pliocene." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 40, 1939. "San Diego horizon." — Hertlein and Grant, Calif. Jour. Min. Geol., Rept. 35 State Mineral., p. 69, 1939. "Pacific Beach" (p. 68), "Pliocene."

Pecten (Lyropecten) ashleyi Arnold, U. S. G. S., Prof. Paper 47, p. 122, pl. 47, figs. 1, 1a; pl. 48, fig. 1, 1906. "The type is from Cerros Island." Also, "in the low hills across the mesa three-fourths of a mile northeast of Pacific Beach, near San Diego." "Pliocene."

Pecten ashleyi [Arnold], J. P. Smith, Calif. State Min. Bur., Bull. No. 72, p. 38, November, 1916. "San Diego and Lower Fernando formations of the coastal region of southern California."

Pecten (Plagioctenium) cerrosensis Gabb, Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 1, p. 15, pl. 6, fig. 1, 1925. (Illustration of Gabb's type specimen).

Pecten (Lyropecten) cerrosensis Gabb, E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 432, pl. 32, fig. 4 (Cedros Island), 1926. Also, "San Diego formation of southern California," Pliocene. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 57, 1944. "Pliocene strata at Pacific Beach" (p. 56). — Hertlein and Grant, Calif. State Div. Mines, Bull. No. 170, chapter 2, p. 60, 1954. "San Diego formation." Pliocene. — Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 44, pl. 20, figs. a, b, 1968. Chula Vista, Pliocene.

Pecten (Lyropecten) estrellanus (Conrad) variety *cerrosensis* Gabb, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 187, pl. 8, figs. 1a, 1b, 2a, 2b; pl. 9, fig. 2 (specimens illustrated from southern California), 1931. "San Diego (Dall and Stearns in Arnold)."

Lyropecten cerrosensis Gabb, Woodring, U. S. G. S., Prof. Paper 190, p. 32, pl. 7, figs. 1, 2 (specimens illustrated from Los Angeles), 1938. Arnold's record of *P. ashleyi* from northeast of Pacific Beach cited (p. 33). — Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, p. 113, 1940 (issued June 7, 1941). "Sea cliff at Pacific Beach." Pliocene. — Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 207, p. 85, pl. 21, fig. 1 (from Santa Maria district), 1950. P. 104, Pacific Beach; "(second bench back on mesa, 3/4 mile northeast of Pacific Beach)"; p. 106, "San Diego formation," "Pliocene." — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. "San Diego formation," also Niguel Formation and others.

Lyropecten (s. s.) estrellatus cerrosensis Gabb, Glibert and Van de Poel, Mém. Inst. Roy. Sci. Nat. Belgique, Deuxième Sér., Fasc. 78, p. 24, 1965. Pacific Beach, San Diego Co., California, Pliocene.

Type specimen. — No. 1091, University of California, Department of Paleontology.

Type locality. — "Cerros Island, off the coast of Lower California: probably Miocene."

Range. — Middle Pliocene of southern California (460) and northwestern Lower California and Cedros Island.

Occurrence in San Diego Fm. — C.A.S. 547, 1179, 1413, 1414, 12142, 28159, 28894. L.A.M. 122, 305, 305C.

Original description. — Shell equivalve, subcircular, broader than long, convex; beaks small; sides sloping concavely above, rounded below; ears small, subequal, roughened and irregular, sinus very small. Surface marked by eighteen or twenty flat ribs, with flat or slightly concave interspaces; margins undulated, the ends of the ribs being deeply emarginated, and the interspaces being prolonged into tongue-like processes. (Gabb.)

Remarks. — The type specimen of this species was discussed and illustrated by the senior author, 1925. The dimensions of the type are, height, 210 mm, length, 220 mm, convexity (both valves together), 90 mm, umbonal angle, approximately 110°. The entire shell is radially striated with fine threads as are other species of *Lyropecten*. The interspaces bear four or five striations or threads of which the central one is stronger than the others and forms a midrib. As pointed out in earlier discussions, the specimen referred by Arnold (1906, pl. 49, figs. 1, 1a, 1b) to *Pecten cerrosensis* is referable to other species and the species which he described under the name of *Pecten (Lyropecten) ashleyi* is now believed to be identical with Gabb's species.

A large, well preserved specimen in the collections of the San Diego Society of Natural History, from Telegraph Canyon, near Chula Vista, is 193 mm long, 179 mm high, the convexity (both valves together) 88 mm. Most of the specimens of *C. (L.) cerrosensis* in collections from San Diego which we have examined are single valves and all except two from near the Mexican boundary are from or near Pacific Beach. A well preserved right valve, 146 mm long and 138 mm high, agrees in all details with specimens from southern California referred to *C. (L.) cerrosensis* (or *Pecten ashleyi*). It has 17 well developed and radially striated ribs. One of the threads in the center of the interspaces is coarser than the others and forms a midrib. Another right valve, from Loc. 1413 (CAS), has 18 radial ribs. Another specimen, the umbonal portion lacking, but apparently a right valve, has 19 radial ribs with the midrib in the interspaces only weakly developed. A right valve, 146 mm long and 138 mm high, from Loc. 305C (LAM), near the Mexican boundary, with 18 radial ribs and somewhat subdued radial striation, agrees in all particulars with specimens of *C. (L.) cerrosensis* from strata of Pliocene age on Cedros Island.

The general characters of the shell of the present species closely resemble those of *C. (L.) estrellanus* (461), a species of late Miocene age. A midrib is present in the interspaces between the ribs of *C. (L.) cerrosensis* as it is in *C. (L.) estrellanus* and its subspecies. However, the midrib is usually decidedly finer than it is on the shells of of the *C. (L.) estrellanus* group. Some young specimens of *C. (L.) cerrosensis* have a well developed midrib and in this respect closely resemble some specimens of *C. (L.) estrellanus*. Compared to typical *C. (L.) estrellanus* Conrad (see Arnold, plate 20, fig. 1) the valves of *C. (L.) cerrosensis* are less inflated, generally larger, more elongated posteriorly, the midrib in the interspaces is usually smaller and not split at the margin, there are more numerous riblets on the ears and often there are more and coarser radial threads and riblets on the posterior

submargin. *Chlamys (L.) cerrosensis* has more numerous ribs which are usually more rounded than those on *C. (L.) estrellanus terminus* Arnold (462) which has but 15 flat-topped ribs. The valves of *C. (L.) cerrosensis* are more convex and the midribs are usually finer than are those of *C. (L.) estrellanus catalinae* Arnold (463). *Chlamys (L.) gallegosi* E. K. Jordan and Hertlein (464) bears a close resemblance to *C. (L.) cerrosensis* but the former species has flatter, squarer, and much more closely spaced ribs, the riblet in the interspaces is much coarser and the radial threads on the shell are generally coarser.

In general outline and sculpture *C. cerrosensis* bears a similarity to *C. (L.) crassicardo* Conrad (465) but differs in possessing a midrib in the interspaces between the major ribs, in the usually greater number of ribs, 17 to 19 or 20 in comparison to 14 to 17, also in lacking constrictions which often are present on the shell of Conrad's species.

GENUS *HINNITES* DEFRANCE

Hinnites Defrance, Dict. Sci. Nat., Vol. 21, p. 169, 1821. Species cited, *Hinnites cortesyi* Defrance and *Hinnites dubuissoni* Defrance. — Cossmann and Peyrot, Act. Soc. Linn. de Bordeaux, Vol. 68, p. 141 (Conch. Néog. de l'Aquitaine, Vol. 2, livr. 2, p. 341), 1914. "G. -T.: *Ostrea crispa* Broc.; = *Hinnites cortesii* Defr. Miocène et Pliocène." — Grau, Allan Hancock Pac. Exped., Vol. 23, p. 133, 1959. Type, *Ostrea crispa* Brocchi, 1814 = *Hinnites cortesyi* Defrance, 1821.

Hinnita Férussac and Deshayes, Tabl. Syst. Anim. Moll., Tabl. Syst. Généraux, p. XL, 1822. [No species mentioned.] Type designated by Gray (Ann. Philos., New Ser., Vol. 12, Art. 4, p. 103, August, 1826): *Lima gigantea* Gray.

Hinnita Gray, Ann. Philos., Vol. 10, New Ser., p. 104, August, 1826. Emendation of *Hinnites* Defrance. "It [*H. gigantea*] may be considered as the recent type of that genus." On p. 362, November, 1826, "The name of this genus must be changed to *Hinnus.*"

Type species (designated by Gray, Proc. Zool. Soc. London for 1847, p. 201). — "*H. Corteysii*" [= *Hinnites cortesyi* Defrance, Dict. Sci. Nat., Vol. 21, p. 169, Atlas, pl. 86, figs. 1, 1a, 1821 = *Ostrea crispa* Brocchi, Conch. Subappen., Vol. 2, p. 567, 1814. "Fossile nel Piacentino," Italy. Illustrated by Roger, Mém. Soc. Géol. France, Nouv. Sér., Vol. 17, Fasc. 2-4, Feuilles 7-43, Mém. No. 40 (completion of Mém. de Paléo., No. 26), p. 172, pl. 23, figs. 11, 12; pl. 25, figs. 1-3 (figs. 1 and 3 "type de *H. cortesyi*"); pl. 28, figs 2, 1939 (as *Chlamys crispa*). "Pliocène inférieur du Plaisantin".]

Range. — Oligocene to Recent. Recent from low tide to 110 meters (60 fathoms).

Description. — Shell to an altitude of about 20 or 30 mm resembling *Chlamys*, then becoming sessile, the shell becomes irregular, thickened, and the resilial pit elongated.

Remarks. — The relationships of many members of this group of mollusks are not known with certainty. It is believed that some species of *Chlamys* become attached and assume a *Hinnites* form. Fisher (466) studied the anatomy of *Hinnites sinuosus* Gmelin (= *Pecten pusio* Linnaeus) and stated that no essential differences exist between the soft parts of that and other species of *Hinnites* and those of *Pecten*. This lends credence to the view of various authors that the genus *Hinnites* is polyphyletic, including species of similar form but genetically not closely related. This view has been accepted by Dall (467) and others.

Prohinnites was proposed by Gillet (468) for Cretaceous species which she considered to bear no relationship with similar Tertiary forms. Species from Jurassic strata which Rollier (469) referred to *Hinnites* are now placed in different genera.

Despite the obvious differences in the genetic relationships of the species referred to *Hinnites*, the shell characters are so similar that for convenience it seems best to apply this generic name to the various Cenozoic species.

One species of *Hinnites* has been reported to range from early Miocene to Recent in California. Some authors consider the Miocene form to be separable as a subspecies. Finlay and Marwick mentioned that in New Zealand, *Hinnites* first appeared in beds of Awamoan, middle Miocene age.

Hinnites giganteus Gray
Plate 41, Figure 16

Lima gigantea Gray, Ann. Philos., New Ser., Vol. 9, p. 139, 1825. [No locality cited.]

Not *Plagiostoma gigantea* J. Sowerby, Miner. Conch., Vol. 1, p. 176, pl. 177 (two figs.), 1814. "This species is found in great variety in the Bath Lyas or Foetid Limestone." England, Jurassic. [Family Limidae.]

Ostrea gigantea [Gray] Wood, Index Test., Suppl., p. 7, pl. 2, *Ostrea*, fig. 7, 1828. Habitat unknown.

Hinnita poulsoni Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 1, p. 182, pl. 14, October, 1834. "The habitat is unknown to me" (Conrad.)

Not *Pecten poulsoni* Morton, Synopsis of the Organic Remains of the Cretaceous Group of the United States, p. 59, pl. 19, fig. 2, early in 1834.

Hinnites giganteus Gray, Sowerby, Thes. Conch., Vol. 1, p. 80, pl. 20, figs. 5-7, November 2, 1842. [No locality cited.] — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 63, pl. 25, figs. 1a, 1b, 1924. Aleutian Islands to Magdalena Bay, Lower California, Recent. Also cited from Pliocene and Pleistocene of California. — Adam, Bull. Inst. Roy. Sci. Nat. Belgique, Tom 36, No. 20, p. 1, footnote, pl. 2, figs. 3a, 3b, 1960. Balboa, California, Recent.

Pecten rubidus Hinds, varietas (?), Middendorff, Beitrage zu einer Malacozoologia Rossica, Mém. Sci. Nat. de l'Acad. Impér. des Sci. de St.-Pétersbourg, Vol. 6, Pt. 3, p. 528 (separate Vol., p. 12) (in part), pl. 13, figs. 4, 5, 6, 1849. "die Insel Sitcha (Wosness)."

Not *Pecten rubidus* Hinds, 1845.

Pecten (Hinnites) giganteus Gray, Kobelt, Syst. Conchyl.-Cab. von Martini und Chemnitz, Bd. 7, Abt. 2, p. 252, Taf. 66, figs. 1-3, 1888. West coast of United States from California to Straits of Juan de Fuca, Recent. — Arnold, U. S. G. S., Prof. Paper 47, p. 93, pl. 29, figs. 1 (type of *H. crassa* Conrad), 2 (San Diego, Recent), 1906. P. 94, "Pliocene. Pacific Beach, San Diego (Arnold)."

Pecten (Chlamys) multirugosus Gale, Trans. San Diego Soc. Nat. Hist., Vol. 5, No. 9, p. 92, February 29, 1928.

Pecten (Pecten) multirugosus Gale, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 159, pl. 11, figs. 5a, 5b (San Pedro, Calif., Recent), 1931. P. 160, "Pacific Beach, San Diego (Arnold)."

Hinnites multirugosus Gale, Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull., No. 90, p. 41, fig. 7, 1953. "Queen Charlotte Islands, British Columbia, to Abreojos Point, Baja, California." — Grau, Allan Hancock Pac. Exped., Vol. 23, p. 134, pls. 45-49, 1959. Earlier records cited.

Type specimen. — In British Museum (Natural History) (A. M. Keen, written comm., February 8, 1967); of *Pecten (Chlamys) multirugosus* Gale, No. 5, San Diego Society of Natural History.

Type locality. — No locality originally cited. Of *Pecten (Chlamys) multirugosus* Gale, "The type is a Recent specimen from San Diego," California.

Range. — Early Miocene (Fritsche); middle Miocene (Temblor, "cf." [Loel and Corey]); late Miocene to Recent. Recent from the Aleutian Islands, Alaska, to Magdalena Bay, Lower California, Mexico, in sheltered waters from high tide to a depth of 55 meters (30 fathoms). In northern waters it lives close to shore and in shallower water (Fitch).

Occurrence in San Diego Fm. — L.A.M. 305, 309, Pacific Beach, at letter "h" in Pacific "Beach" Junior High School shown on U. S. G. S. topog. map, La Jolla quad.

Original description of *Lima gigantea* Gray, 1826. — "T. oblonga, extus pallidè brunneâ confertim radiato-sulcatâ, extus alba, margine cardinali purpurea: Long. 4, alt. 5 poll."

"Irregularly oval, thick, radiately striated, with the ears small, narrow, hinge thick; colour pale brown, with reddish radiating streaks, inside white, hinge purple." (Gray.) (Ann. Philos., New Ser., Vol. 12, p. 103, 1826.)

"The young of this species is a typical *Chlamys* up to the size of 20 or 30 mm. The left valve resembles closely the left valve of *Pecten hastatus* Sowerby, or the young of some specimens of *Pecten squamatus* Gmelin from Japan, being sculptured with small radiating ribs, every fourth or fifth raised above the others and covered with spines. It is about the shape of *P. squamatus* but is slightly more circular than *P. hastatus*. The right valve does not have the high paired ribs of *P. hastatus*, but has low ribs, flattened on top, nearly all the same size with only occasionally a slight accentuation of every third. As soon as the young *Chlamys* assumes a sessile position, the growth becomes very irregular, influenced considerably by the shape of the object to which it is attached, the ribs become coarser and spinose, and the shell thickens rapidly, oyster-like, especially the right (the lower) valve which may in the process develop a greatly elongated resilial pit." (For *Pecten (Chlamys) multirugosus* Gale, 1928.)

Remarks. — A left valve of this species, about 74.3 mm long and 84 mm high and 35.5 mm in convexity, was collected by G. P. Kanakoff at Loc. 305 (LAM) near the Mexican boundary. It is more convex than is usual for this species but otherwise it is similar to Recent specimens. A right valve, 73 mm long and 76 mm high was collected by J. F. Arndt near Pacific Beach Junior High School. A fragment, probably this species, was collected by Kanakoff at Loc. 309 (LAM).

The taxon "*Pecten (Chlamys) multirugosus*" was proposed by Gale, 1928, to replace *Lima gigantea* Gray, 1825, because of the earlier *Plagiostoma gigantea* J. Sowerby, 1814. Gale considered *Plagiostoma* to be a subgenus of *Lima*, in which case Gray's species became a secondary homonym. *Plagiostoma* J. Sowerby (1814, p. 175) was originally described as a genus and it is so used by many modern authors. Under this usage the combination *Lima gigantea* Gray is not a homonym and the specific name "*giganteus*" is nomenclaturally valid in combination with the genus *Hinnites*. We favor retention of this well known combination of names believing that this lends stability to the nomenclature of this species. Adam (1960) recently maintained the validity of this taxon.

If the name *Hinnites giganteus* be abandoned the next available name is "*Hinnita*" *poulsoni* Conrad. This name is not a homonym of the earlier *Pecten poulsoni* Morton, as believed by Grant and Gale. The type locality of *H. poulsoni* Conrad is unknown but nearly all authors who have considered the taxonomic status of this species have placed it in the synonymy of *H. giganteus*.

Hinnites crassa Conrad (470), described from beds of late Miocene age in California was renamed *crassiplicatus* by Gale (471) as a variety of the Recent form *multirugosus*. However, the name of Conrad's species is not preoccupied by *Pecten crassus* Risso, 1826, and no replacement is necessary. Gale believed the Miocene form to be smaller, usually with the *Chlamys* stage lasting longer, with less irregular growth and with fewer more highly differentiated coarse, rugose radial ridges. The taxonomic value of the name applied to this form is open to question. It may be a subspecies of the Recent form but Arnold (472) considered it to be identical with the Recent species and we are inclined to that view. Woodring and Stewart (473) reported "*Hinnites* cf. *H. crassa* Conrad" from the Etchegoin Formation, late Pliocene, in the San Joaquin Valley. *Hinnites benedicti* Adegoke (474), from the Santa Margarita Formation of late Miocene age, was described from the same region.

Dollfus and Dautzenberg (475) mentioned that a series of specimens of *Hinnites crispa* from late Tertiary beds in Europe reveals variations analogous to those of *H. giganteus*.

A paper by Yonge (476) contains the results of a study of the habits of Recent *H.* "*multirugosus*". He stated that attachment to the substratum takes place when the shell is between 2.2 and 4.2 cm high.

This species attains a large size in northern waters. Eyerdam (477) mentioned a specimen from the San Juan Islands in Puget Sound which was 222 mm (8 3/4 inches) long, 168 mm (6 1/2 inches) wide, and near the byssal plug the valve was 64 mm (2 5/8 inches) thick. The lower valve weighed 3 pounds and 1 ounce. This species is gathered for food, only the large adductor muscle is eaten. A huge specimen 230 mm long, was reported by T. Meagher from Santa Cruz Island, California. (The Echo: Western Soc. Malacol., p. 38, 1968).

Henderson (478) pointed out that Bryan's (479) record of *H. giganteus* in Hawaii is referable to a species of *Spondylus*. Records of *H. giganteus* from the Coralline and the Red Crag in England were referred by Woods (480) to *H. cortesyi* Defrance.

GENUS *CYCLOPECTEN* VERRILL

Cyclopecten Verrill, Trans. Connecticut Acad. Arts and Sci., Vol. 10, Pt. 1, p. 70, 1899 [issued June, 1897]. "Types, *Pecten pustulosus* Verrill; *P. imbrifer* Loven." — Marwick, Trans. New Zealand Inst., Vol. 59, Pt. 4, p. 909, 1929. "Type: *Cyclopecten postulosus* Verrill." — Grau, Allan Hancock Pac. Exped., Vol. 23, p. 21, 1959. "Type species: *Pecten pustulosus* Verrill, 1873."

Cycopecten (err.) de Gregorio, Ann. de Géol. et Paléo., Livr., 23, p. 43, 1928.

Cyclochlamys Finlay, Trans. New Zealand Inst., Vol. 57, p. 452, issued separately, December 23, 1926. "I supply for it [*Pecten transenna* Suter, Man. New Zealand Moll., p. 881, pl. 52, fig. 3, 1913. "Near the snares, in 50 fathoms (type), New Zealand, Recent] the new generic name *Cyclochlamys.*" — Marwick, Trans. New Zealand Inst., Vol. 58, Pt. 4, p. 453, 1927, published separately February 28, 1928. [Use of *Cyclochlamys* discussed.]

Not *Ciclopecten* Seguenza, Boll. Comit. Geol. Ital., Vol. 8, Nos. 9-10, p. 362, 1877. Sole species: *Ciclopecten peloritanus* Seguenza, p. 362, 1877. Messina, Pliocene.

Type species (designated by Sykes, Smith, and Crick, Zool. Rec., Vol. 34, Moll., p. 75, 1898). — "type: *C. pustulosus*, Verrill" [= *Pecten pustulosus* Verrill, Amer. Jour. Sci., Ser. 3, Vol. 5, p. 14, January, 1873. "Near St. George's Bank (s), in 150 fathoms, mud (living); east of St. George's (g) in 430 fathoms, sand and gravel (dead, but fresh valves.)" off Newfoundland. — Verrill, 1897, p. 70, fig. 1 (as *Cyclopecten pustulosus).* — Verrill and Bush, Proc. U. S. Nat. Mus., Vol. 20, No. 1139, p. 839, pl. 85, figs. 5, 6, 10, 11, 1898 (as *Cyclopecten pustulosus)*].

Range. — Late Miocene to Recent. Recent, Atlantic; eastern Pacific; New Zealand region; in 5 to 2323 meters (3 to 1270 fathoms).

Original description: Shells thin, rounded, scarcely oblique, with symmetrical auricles and simple margins. The two valves are quite unlike in sculpture. The right valve is a little flattened and upturned at the flexible margin, so as to fit tightly against the upper valve. The thin lower valve has, in the typical species, regular, thin, elevated concentric lamellae, which aid in the adaptation of the edge to that of the upper valve; the margin is usually flattened or bevelled. The upper (left) valve is radially sculptured, rarely smooth; it usually has radial rows of arched scales, pustules, or points, and also concentric raised lines; it is sometimes cancellated. No radial ribs, nor interlocking points at the margin. Auricles well developed, subequal, angulated and well-defined at both ends; byssal notch well defined; few or no pectinidial teeth. Cardinal folds single, rather feebly developed, often cross-lined. Eyes few. Byssus small, and of few threads. (Verrill.)

Remarks. — Grau (1959, p. 22) mentioned that "Some species do not have the ventral margin of the right valve flexed, and one, *Cyclopecten acutus* sp. nov., does not have concentric lamellae or ridges on that valve. Most species are translucent but a few are opaque". He included twelve west American species in *Cyclopecten.*

The shells of species of *Cyclopecten* are prismatic in structure. Some of the species with flexed ventral margin of the right valve resemble some species of *Propeamussium* (481) but differ in lacking internal radial rays.

Chlamydella Iredale (482) differs from *Cyclopecten* in the elongated (anterior-posterior) form and in that the right valve is sculptured with fine radial riblets separated by raised scales, the left with fine concentric raised threads.

Barnard (483) described *Cyclopecten incubans* from South Africa which contained juvenile forms. He pointed out that this apparently is the first reported occurrence of incubation in the Pectinidae.

Cyclopecten pernomus Hertlein
Plate 33, Figures 7, 11

Pecten (Cyclopecten) rotundus Dall, Bull. Mus. Comp. Zool. Harvard Coll., Vol. 43, No. 6, p. 404. "U. S. S. 'Albatross', station 2799, in Panama Bay, in 29 1/2 fathoms; also at station 2784, in 194 fathoms, mud, bottom temperature 51.9° F. U. S. N. Mus. 110, 708."

Not *Pecten rotundus* von Hagenow, 1842, p. 554. Chalk on Rügen Island in Baltic Sea, Cretaceous.

Pecten (Cyclopecten) pernomus Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 21, No. 25, p. 320, pl. 18, figs. 11-13, September 26, 1935. Dall's localities cited, also others. A new name for *Pecten (Cyclopecten) rotundus* Dall, 1908, not *Pecten rotundus* von Hagenow, 1842.

Cyclopecten pernomus Hertlein, Grau, Allan Hancock Pac. Exped., Vol. 23, p. 32, pl. 11, September, 25, 1959. Numerous localities cited from western Lower California to Ecuador. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 72, fig. 135, 1958. Cedros Island, Lower California to Panama.

Amusium (Cyclopecten) pernomus Hertlein, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 168, pl. 21, fig. 6, 1961. Cedros Island, Lower California, to Panama, Recent.

Type specimen. — No. 110, 708, United States National Museum.

Type locality [of *Pecten (Cyclopecten) rotundus* Dall]. — "U. S. S. 'Albatross', station 2799, in Panama Bay in 29 1/2 fathoms."

Range. — Middle Pliocene to Recent. Recent from Cedros Island, west coast of Lower California, Mexico, and Angel de la Guardia Island in the Gulf of California, to La Libertad, Ecuador. Also Guadalupe Island and Galapágos Islands (Grau). In 2 to 1,720 meters (1 to 940 fathoms) (484). "Usually found in mud bottoms, occasionally sandy mud or sand; sometimes associated with eel grass or weed" (Grau).

Occurrence in San Diego Fm. — L.A.M. 305A, 305C.

Original description (of *Pecten (Cyclopecten) rotundus* Dall). — Shell very small, thin, white, suborbicular, with subequal ears, both valves nearly equally convex; right valve polished, minutely regularly concentrically striated, which sculpture is barely visible under a hand lens; posterior ear smooth, anterior finely radially threaded, with a narrow but clean-cut byssal sulcus and fasciole; left valve finely sharply radially striated, the anterior ear finely reticulated, the posterior apparently nearly smooth; hinge line short, straight; interior smooth, a pair of small auricular crura present; the hinge line with a minute central pit and two relatively large transversely sharply striated, elongate areas representing a permanent provinculum. Height and length, 3; hinge line 2.5; diameter, 1.0 mm. A single valve from near the Straits of Magellan, apparently

the same species, measures 7 mm in height. (Dall.)

Supplementary description. — The right valve is slightly smaller than the left. Its anterior auricle has concentric as well as radial striae; its posterior auricle is not "smooth", having 7 to 11 fairly prominent radial threads and finer concentric threads. The posterior auricle of the left valve is not "nearly smooth," having both fine radial and finer concentric threads. On about half of the hundreds of left valves examined there were gray-brown, yellow-brown, red-brown or deep brown areas, irregular and varying in size; the right valves were all white. Specimens measuring 10 mm in altitude were taken at Hancock station BS 2130, Pond Island, northern Gulf of California, in 62-85 fathoms; the largest specimens previously recorded were 7 mm in altitude. (Grau.)

Remarks. — Ten single valves varying in degree of preservation, are present in the collection of Los Angeles County Museum from Locs. 305A and 305C (LAM) from near the Mexican boundary. The largest is about 5.5 mm long. Some of them retain traces of the brownish color markings on the ventral portion of the shell.

These specimens agree in all shell characters with Recent specimens of *Cyclopecten pernomus* dredged in tropical west American waters. Gilbert Grau agrees with this assignment. This is the first record of the occurrence of this species in the fossil state.

Cyclopecten pernomus lacks the distinct posterior flexure which is present on the right valve of *C. cocosensis* Dall (485). The auricles of *C. pernomus* are much less acutely pointed than those of *C. acutus* Grau (486) from West Colombia and the left valve is sculptured with concentric ridges rather than with fine radial threads.

Grau (1959, p. 33) pointed out that the single valve from the Strait of Magellan which Dall believed to be probably referable to "*Pecten (Cyclopecten) rotundus*" [= *C. pernomus*] is not conclusive evidence that this species lives in those southern waters.

SUPERFAMILY LIMACEA RAFINESQUE
FAMILY LIMIDAE RAFINESQUE (487)

Shell monomyarian or with a single adductor scar, obliquely subpectiniform with small, narrow ears and median beaks, equivalved, inequilateral, the shorter side being posterior, usually white, externally sculptured with fine or coarse, generally scabrous radial riblets. Lateral margins generally thickened, the anterior one with an open gap. Hinge line straight, edentulous, or with obscure denticulations on the side, the cardinal area high, subtriangular with a central resilial pit under the beak in each valve. A thin brown deciduous periostracum is often present. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca New York), p. 169, 1961.) Late Paleozoic (Carboniferous) to Recent.

Remarks. — The triangular ligamental pit in this family is external, rather than internal, and the position of the adductor impression is higher and more posteriorly situated than it is in the Pectinidae. A byssus may be present or lacking, but if present it extends through a slight gape in the valves. Some members lacking a byssus are active swimmers.

Early members of this family, so abundant and large in the Mesozoic Era, were discussed by Cox (488).

GENUS *LIMA* BRUGUIÈRE

Lima Bruguière, Encyl. Méth. (Tabl. Vers.), pl. 206, 1797. [Name and figure only.] — Cuvier, Tabl. Elém. Hist. Nat. Anim., p. 421, AN 6 [1797 (489).] Sole species, *Lima alba* Cuvier with *Ostrea lima* Linnaeus in synonymy. — Gardner, U. S. G. S., Prof. Paper 142-A, p. 52, 1926. "Type: *Ostrea lima* Linnaeus." — Vokes, Tulane Studies in Geol., Vol. 1, No. 2, p. 75, 1963. "Type species by subsequent tautonomy (Lamarck, 1801) *Ostrea lima* Linnaeus, 1758 = *Lima squamosa* Lamarck, 1801, Recent, apparently world wide in warmer waters."

Type species (by tautonomy, Cuvier, 1797). — *Ostrea lima* Linnaeus (in the synonymy of *Lima alba* Cuvier). [*Ostrea lima* Linnaeus, Syst. Nat., ed. 10, p. 699, 1758. "Habitat in O. meridionali." Ref. to "Argenv. Conch. t. 27, f. E." This was illustrated without specific name by Bruguière, 1797, pl. 206, fig. 4 and it was described under the name of *Lima squamosa* by Lamarck, 1801, and by Deshayes, Encyl. Méth., Vol. 3, p. 345, 1832. Also illustrated by Sowerby, Reeve's Conch. Icon., Vol. 18, *Lima*, sp. 10, pl. 2, fig. 10, 1872 (as *Lima squamosa* Lamarck). For a discussion of *Ostrea lima* Linnaeus see Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 186-187, 1952; also Vokes, 1963, pp. 75-76.]

Range. — Triassic to Recent. Shallow to deep water.

Description. — Shell equivalve, inequilateral, biconvex, oblique, auriculate, edentulous, usually gaping anteriorly; the anterior region larger than the posterior, in which the umbones are situated. Posterior auricle larger than or equal to the anterior. Hinge-line straight, short. Area triangular, with a central ligament pit. Adductor impression large. Two small pedal impressions. (Arkell, W. J., Palaeongraphical Society London, Vol. 83, Corall. Lamell., Pt. 3, p. 128, 1931.)

Remarks. — Most members of this group are ornamented with radial ribs which may be nearly smooth or scaly. The exterior of others may be nearly smooth.

Lima is represented by abundant species in beds of Mesozoic age but their number declined during the Cenozoic. Only three species are known to occur in beds of Pliocene age in California, and these are rarely found. The genus is here recorded from the San Diego Formation for the first time. Species of *Lima* are widely distributed in the seas at the present time; eleven species have been reported living in west American waters.

Species of this genus can swim by clapping the valves together and expelling currents of water from the mantle cavity. Some species spin "nests" in which they are enclosed.

SUBGENUS *LIMARIA* LINK

Limaria Link, Beschreib. Nat. -Sammlung Univ. Rostock, Abt. 3, p. 157, May 17, 1807. Species cited include "*L. inflata.*" — Winckworth, Proc. Malacol. Soc. London, Vol. 19, Pt. 3, p. 116, November, 1930. "I here choose *inflata* as type." — Hertlein and Strong, Zoologica, Vol. 31, Pt. 2, No. 5, p. 66, 1946. Type as designated by Winckworth.

Mantellum Bolten, Mörch, Cat. Conch. Comtes de Yoldi, Fasc. 2, p. 57, 1853.

Not *Mantellum* Röding in Bolton, Mus. Bolt., p. 160, 1798.

Winckworthia Glibert and Van De Poel, Mém. Inst. Roy. Sci. Belgique, Deuxième Sér., Fasc. 78, p. 49, 1965. "Type.—(Ice désigné), *Ostrea tuberculata* Olivi, 1972." [Zool. Adriatica, p. 120. "Abita nei fondi arenosi misti del mar dirimpetto alla spiaggia occidentale." Ref. to Gualtieri, Test., Tab. 88, fig. FF.]

Type species (by subsequent designation, Winckworth, 1930). — *Limaria inflata* Link founded on Chemnitz (490), Conchyl. -Cab. Bd. 7, pl. 68, fig. 649, lit. a [cited as "641.a" by Link], 1784. "Kuste von Guinea und an den Stranden der westindischen Zuckerinsuln." [= *Ostrea tuberculata* Olivi, 1792.]

Range. — Early Cretaceous (Neocomian) to Recent.

Description. — Shell of medium size (larger ones about 40 mm high), moderately thin, oblique, posterior margin bulging; submargins not impressed; usually somewhat inflated, gaping anteriorly and often more so posteriorly; sculptured with rather fine ribs of variable size, often scaly; ligament pit broadly triangular; a small but well developed pit beneath the posterior ear and usually a weaker one under the anterior ear; foot without byssus or retractor.

Remarks. — *Limaria* is here recorded from the San Diego Formation for the first time.

Species of this subgenus, at the present time, live in temperate and tropical waters. One species lives in Californian waters.

Promantellum Iredale (491) differs but little from *Limaria* except that the valves of the type species may be more widely gaping.

Submantellum Olsson and Harbison (492), with the type *Lima orbignyi* Lamy, differs from *Limaria* in the greater inflation of the valves, which gape but slightly anteriorly and lack any gape posteriorly.

A paper by Studnitz (493) deals with the anatomy of two of the small Atlantic species of *Limaria*.

Lima (Limaria) orcutti n. sp.
Plate 35, Figure 11; Plate 36, Figures 2-5;
Plate 57, Figure 10

Description. — Right valve, shell obliquely elliptical in outline, inequilateral, moderately convex; greatest length (anterior-posterior) about halfway between beak and ventral margin, gaping along the posterior dorsal margin; hinge short, oblique, the posterior ear pointed, a shallow sinus immediately below it; the anterior margin nearly straight above, but below it is gently rounded into the ventral margin, the outline of the posterior and ventral margin forms a braod arc; anterior umbonal slope rather steep, the posterior slope rather gentle; the valves are sculptured with about 35 to 40 fine, radial riblets, some vaguely paired, all separated by wider interspaces, ribs and interspaces widest on medial portion of the valve, the whole crossed by fine imbricating lines of growth; hinge elongately triangular, with a broad shallow, triangular ligamental pit, a triangular pit under the posterior ear, a shallow depression under the anterior one; the interior smooth, in some places the external ribbing is visible. Dimensions of holotype: Height (beak to ventral margin) 43 mm, length approximately 35.5 mm (posterior side imperfect), convexity (left valve) approximately 9.6 mm.

Type specimen. — Holotype and paratype in Los Angeles County Museum.

Type locality. — Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U. S. G. S., topog. map, San Ysidro quad., rev. 1953.)

Range. — Middle Pliocene (San Diego formation).

Occurrence in San Diego Fm. — L.A.M. 305, 305C, 319.

Remarks. — This species is represented in the present collection by five valves, fairly well preserved, and by a number of fragments. The largest of the valves, a right valve, is selected as holotype.

This new species bears a general resemblance to *Lima hemphilli* Hertlein and Strong (494) which now lives in adjacent waters but the new species has fewer, coarser, more widely spaced ribs, the greatest length of the valves (anterior-posterior) is at a point about midway between the beak and the ventral margin rather than above the middle, the hinge plate is relatively broader and the posterior ear is much less acutely pointed.

The general features of the hinge are more like that of *Lima orbignyi* Lamy (495), but the shell of the new species is much more elongated, less inflated and the valves gape posteriorly.

The general outline of this new species is somewhat like that of *Lima auaua* Dall, Bartsch, and Rehder (496), from Hawaii, but the character of the ribbing appears to be quite different.

SUPERFAMILY OSTREACEA RAFINESQUE (497)
FAMILY OSTREIDAE RAFINESQUE (498)

Shell porcelaneous, inequivalve, dimyarian when young, monomyarian when adult, with posterior adductor impression in each valve; edentulous (or obscurely so); attached by cementation by the umbo or by the whole outer surface of the left valve to rocks, roots of trees or other objects; valves often much distorted due to fixation; valves usually close fitting, the left one usually larger and deeper, the right one often flat; sculpture alike on the two valves or different. Marine or brackish water. [Adapted from Dall in Eastman's edit. of Zittel's text book of Paleo., Vol. 1, pp. 451-452, 1913, and Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York) p. 171, 1961.] Triassic to Recent.

Remarks. — Newell (499) recently suggested that the pseudomonotids may have been ancestral forms giving rise to oysters. He mentioned that "true oysters are distinguished by loss of the foot and byssus during the prodissoconch stage, cementation by the left valve, and possession of a calcite shell. The last two characteristics apparently were not acquired before early or middle triassic time . . . ."

An excellent summation of the various supraspecific group names in this family and their type species was published by Stenzel (500), and Baughman (501) published an annotated bibliography of oysters.

GENUS *OSTREA* LINNAEUS

Ostrea Linnaeus, Syst. Nat. ed. 10, p. 696, 1758. Many species cited including *Ostrea edulis* Linnaeus. — Dall,

Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 671, 1898. "Type *Ostrea edulis* Linné." — Lamy, Jour. de Conchyl., Vol. 73, No. 1, p. 12, 1929. "Type *O. edulis* L."

Ostreum DaCosta, Hist. Nat. Test. Brit., p. 154, 1778. Type designated by Winckworth (Proc. Malacol. Soc. London, Vol. 17, Pts. 2 and 3, p. 106, December 1926): "*T. vulgare*, da C. (here chosen) = *Ostrea*, L."

Ostracites Gmelin, Linn. Syst. Nat., ed. 13, p. 404, 1793. Type designated by Stenzel (Jour. Paleo., Vol. 21, No. 2, p. 178, March, 1947): "GT: *Ostrea edulis* Linné".

Ostraea G. B. Sowerby, Jr., Conch. Man., ed. 1, p. 75, and on table, 1839. Emendation of *Ostrea* Linnaeus. Suppressed as a synonym of *Ostrea* Linnaeus, see opinion 148, Internatl. Comm. Zool. Nomencl.

Monoeciostrea Orton, Nature (London), Vol. 121, p. 321, March 3, 1928. Type designated by Iredale (Great Barrier Reef Exped., 1928-29. Sci. Repts., Vol. 5, No. 6, Moll., Pt. 1, p. 394, 1939): "Logotype: *Ostrea edulis* Linné."

Type species (by Linnaean tautonymy; also designated by Schmidt, Versuch. Conch. Samml., pp. 69, 177, 1818). — *Ostrea edulis* Linnaeus. *Ostrea* with the type species, *Ostrea edulis* Linnaeus, was placed on the official list of generic names in Zoology by the Internatl. Comm. Zool. Nomencl. (Opinion 94, published October 8, 1926). [*Ostrea edulis* Linnaeus, Syst. Nat., ed. 10, p. 699, 1758. "Habitat in Oceano Europaeo." References include Gaultieri, Test., pl. 102, fig. B; Klein, Ostr., pl. 8, fig. 21; Bonaninni, Recr., t. 70. Also illustrated by Sowerby in Reeve's Conch. Icon., Vol. 18, *Ostraea*, sp. 8, pl. 5, figs. 8a-f, 1870. See also discussion of this species by Dodge (Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 192, 1952). The chalky deposits in the shell of this species were discussed by Korringa (Proc. Calif. Acad. Sci., Ser. 4, Vol. 27, No. 5, pp. 133-158, 2 figs. in text, 1951).]

Range. — Triassic to Recent. Recent, world-wide in temperate and tropical marine and brackish waters, from the intertidal zone to about 91 meters (50 fathoms) but usually abundant in less than 18 meters (10 fathoms). *Ostrea cochlear* is reported (502) from 2174 meters (1,189 fathoms).

Description. — Shell ovate, elongate or irregular in outline, attached by the left valve; upper valve flat or concave or sometimes convex, often unsculptured; lower valve convex, often plicated or foliaceous or with a prominent beak, dimyarian in juvenile state, monomyarian in adult (the anterior adductor lacking); ligamental cavity triangular or elongated; hinge toothless (except in very early stage of growth); margins smooth or with denticles; structure subnacreous, laminated, with prismatic cellular substance between the margins of the laminae. (Adapted from Tryon, Struct. and Syst. Conch., Vol. 3, 1884, p. 297, and Dall in Eastman's edit. of Zittel's Text-book of Paleo., Vol. 1, p. 450, 1913.)

Remarks. — The species of *Ostrea* have been the subject of a vast amount of literature. Much of this is a result of their economic importance because many of the species are highly valued as food. Many of the fossil forms are valuable aids as indicators of the geologic age of the strata in which they occur.

The majority of oysters including all the large, thick shelled forms live in shallow water or on bottoms exposed between tides. The shape and sculpture of the shells of various species varies greatly because of the influence of the character of the bottom, the currents, or the chemical content of the waters in which they live.

A number of species of *Ostrea* have been described from strata of Tertiary age in California (503). One of these *Ostrea titan* Conrad, a huge species of Miocene age, has been reported to attain a length of 457 mm (18 inches). One species and two or possibly three varieties, live in the waters between the Bering Sea and San Diego, California (504). Along with these in some bays is a Japanese species *Ostrea gigas* Thunberg (or the variety *laperousei* Schrenck) and *Ostrea virginica* Gmelin (505) and others, introduced for commercial purposes. About a dozen species and subspecies of this genus live in tropical and subtropical waters of the western Americas (506). The Recent species in the Museum of Natural History in Paris were discussed by Lamy (507), those of Japan by Hirase (508) and those of Australia by Thomson (509).

Five species occur in the San Diego Formation.

Key to Species of *Ostrea*

A. Valves smooth . . . . . *erici*

B. Valves with radial plications

a. Dorsal margins with denticles

b. Valves falcate in outline . . . . *megodon*

bb. Valves roundly trigonal to ovate in outline

c. Upper valve flat fitting into plicate margins of the lower one . *vespertina*

cc. Upper valve slightly arched, margins interlocking with the lower one . . . . . *angelica*

aa. Dorsal margins lacking denticles . . . . *veatchii*

Ostrea angelica Rochebrune
Plate 38, Figures 2, 3

Ostrea cumingiana Dunker of west American authors. — Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 58, pl. 5, fig. 6, 1950. Late Pliocene to Recent in the Gulf of California region.

Not *Ostrea cumingiana* Dunker, Zeitschr. f. Malakozool., Jahrg. 3, p. 48, March, 1846. "Patria ignota." — Philippi, Abbild. u. Beschreib. Neuer oder wenig gekannte Conchyl., Bd. 2, Heft 3, *Ostrea*, p. 81, Taf. 1, figs. 1, 2, 3, 4, October, 1846. "Patria ignota." — Hirase, Jap. Jour. Zool., Vol. 4, No. 2, p. 213, fig. 1, 1932 [as *Ostrea (Lopha) cumingiana*]. Omami, Oshima, Japan. — Adam and Leloup, Mém. Mus. Roy. Hist. Nat. Belgique, Hors Sér., Rés. Sci. Voy. Ind. Orient. Néerland, Vol. 2, Fasc. 20, p. 66, 1939. Manokwari.

Ostrea angelica Rochebrune, Bull. Mus. d'Hist. Nat. (Paris), Vol. 1, p. 241, 1895. "Baie de Los Angeles," east coast of Lower California. — Contreras An. Inst. Biol. (Mexico), Vol. 3, No. 3, p. 207, figs. 18 and 19, 1932. "Bahía de Los Angeles, Golfo de California." —

Keen, Sea shells of Tropical West America (Stanford Univ. Press), p. 65, fig. 117, 1958. "The Gulf of California to Ecuador." — Emerson and Hertlein, Trans. San Diego Soc. Nat. Hist., Vol. 13, No. 17, p. 353, figs. 3a-c, 1964. Isla Angel de la Guardia, ?Pliocene; Isla Carmen, Pliocene.

Type specimen. — Muséum Nationale d'Histoire Naturelle de Paris.

Type locality. — "Hab. Baie de Los Angeles, où elle forme des bancs d'une étendue considérable." [East coast of Lower California.]

Range. — Middle Pliocene to Recent. Recent from San Ignacio Lagoon to San Felipe, Lower California, and south to Mazatlan, Mexico. To Ecuador (Keen). [Not reported from the Panamic region by Olsson, 1961.] At the mouths of estuaries and bays, on stones, etc., where there is a current, but sheltered from breakers.

Occurrence in San Diego Fm. — C.A.S. 28888. S.D. 409. U.C.L.A. 303.

Original description. — O. Testa aggregata, plerumque irregulariter ovoideo rotundata, apice plus minusve attenuata, ad marginem undulato dentata; umbonis arcuatis, ligamento obliquo; valvis inaequalibus; valva inferiore subprofunda, intense adherens, circulariter radiatim costata; costis crassis subangulosis; valva superiore plana, centraliter corrugata, circulariter radiatim costata, costis irregularibus, obtusis plicatis, plicis imbricatis latis; extus albo viridula, intus albo nitida virescente; impressione subcentrali albo, trapezoideo; marginibus lateralibus prope umbonibus, minutissime denticulatis.

Long. 0,080 mm. — Latit. 0,055 mm. — Crass. 0,023 mm. (Rochebrune.)

Remarks. — The fossils here referred to *Ostrea angelica* agree closely in all observable shell characters with Recent specimens of that species from the Gulf of California.

Recent specimens of *O. angelica* are usually oblong or rounded and the shell is rather thick. The lower valve is decidedly convex, the upper one only gently so. Both valves are sharply plicated over the distal half or one third of their surfaces which interlock along the margin, but the plications usually do not extend much beyond the pallial line on the interior of the valves. Exteriorly the color is light green with purplish radial streaks, the interior olive-green or shining whitish-green, occasionally entirely white. Denticles or transverse vermiculations are present on the margins from the ligamental pit usually to about a third the distance to the ventral margin. The muscle impression is posterior to the center, trapezoidal in shape, white. Large specimens in the collections of the California Academy of Sciences from Mejia Island, Gulf of California, are 122 mm high (beak to base), 95 mm long, convexity (both valves together), 41 mm.

Small specimens of *O. angelica* differ from *O. lurida laticaudata* Carpenter (510) in the greater thickness of the shell, the more convex upper valve which is more deeply plicated and along the margin interlocks downward with the lower valve rather than turning upward along the margin and fitting into the scalloped margin of the lower valve. Adult shells of *O. angelica* attain a much greater size and thickness than forms of *O. lurida.*

These same shell characters serve to separate *O. angelica* from *O. palmula* Carpenter, with which it occurs in the Gulf of California. The interior margins of Recent *O. palmula* are blue or purplish blue, rather than tinted with green. Furthermore denticles often are present for a greater distance distally along the margins of *O. palmula* than on *O. angelica.*

The valves of *O. angelica* are generally larger, thicker, and more deeply plicated than those of *O. vespertina.* The plications on the exterior of the valves usually are present only on the distal half or third of the valves of *O. angelica.* On the lower valve these plicae extend from the margin to the broad unplicated area of attachment. The corresponding area of attachment on *O. vespertina* is usually much smaller. Furthermore the upper valve of *O. angelica* is more convex, the plications interlock downward along the margin, whereas on *O. vespertina* the upper valve is almost flat and fits into the scalloped edges of the lower valve similar to that of *O. lurida laticaudata* and *O. palmula.*

Ostrea caboblancoensis Weisbord (511) described from strata of Pliocene age in Venezuela, bears a resemblance to *O. angelica.*

Ostrea angelica is reported here for the first time from the San Diego Formation. It is known to occur on terraces near San Antonio del Mar (512), in beds of Pliocene age, at Cedros Island and at Bahía Tórtolo (Turtle Bay), Lower California, and in strata of Pliocene and Pleistocene age in the Gulf of California region (513).

Ostrea erici Hertlein
Plate 38, Figures 4, 6, 8, 9

Ostrea erici Hertlein, Jour. Paleo., Vol. 3, No. 3, p. 295, September, 1929. A new name for *Ostrea tayloriana* Gabb, E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., 4th Ser., Vol. 15, No. 14, p. 428, pl. 33, fig. 3, 1926. [Not *Ostrea tayloriana* Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 34, pl. 12, figs. 60, 60a, 1866. "Miocene, from San Marcos Pass, near Santa Barbara", California. (Eocene.)] — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 59, 1944. India Street at corner of Upas Street, San Diego. — Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper No. 222, pp. 65, 85, 104, 106, pl. 8, figs. 17, 18; pl. 9, figs. 1, 3, 4, 1950. [All figures represent specimens from Pliocene of Santa Maria district.] P. 104, India and Upas streets; p. 106, San Diego Formation, Pliocene. — Hertlein and Grant, Calif. State Div. Min., Bull. 170, Chap. 2, p. 60, 1954. San Diego Formation, Pliocene. — Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. San Diego Formation. Also Niguel Formation and others.

Type specimen. — No. 2094, California Academy of Sciences, Department of Geology, Type Collection.

Type locality. — From "mouth of big arroyo northwest of Elephant Mesa, Scammon Lagoon Quadrangle, Lower California. Pliocene".

Range. — Middle Pliocene, southern California, and Lower California.

Occurrence in San Diego Fm. — C.A.S. 1135, 1183, 28892, 28893, 33334. L.A.M. 107, 124, 180, 309. S.D. 415, 2912, 2951. U.C.L.A. 309.

Description. — Shell moderately large, elongately to roundly trigonal, sometimes slightly expanded posteriorly; lower valve arched, right (upper) valve flat, both valves composed of rather coarse overlapping shell

laminae; ligamental pit on both valves elongately trigonal, rather small for the size of the shell; hinge plate at end of pit rounded and very slightly overhanging a shallow cavity; a small flat-topped indentation, corresponding to the lines of growth, occurs on each side of the ligamental pit; interior of shell smooth, large adductor impression rounded to semi-lunar, situated on the posterior side dorsally a little over one half the distance from the ventral margin to the beak; body cavity often bounded on each side by smooth, steep walls beyond which the shell tapers to a thin edge; margins smooth, no denticles present. Dimensions of the holotype: maximum length (beak to base), 100.5 mm, transverse length, 78 mm, convexity (both valves together), 36 mm.

Remarks. — This interesting oyster was collected chiefly in the strata exposed on and near Reynard Way and at the end of Arroyo Drive in San Diego. A representative specimen from Loc. 28893 (CAS), is 108 mm high (beak to base), transverse length, 94 mm, convexity (both valves together), 46.9 mm. It was first recorded from beds in northern Lower California by E. K. Jordan and Hertlein. Since then it has been recorded at a number of localities in beds presumably of about the same age as that of the San Diego Formation, namely, at Fourth and Broadway streets in Los Angeles (514), in the Sisquoc Formation and in the Cebada Member of the Careaga Formation in the Santa Maria district, in the Niguel Formation near San Juan Capistrano, in beds of middle Pliocene age on Carmen Island (515) in the Gulf of California, and questionably in the Gloria Formation in the Santa Rosalia area (516), east coast of Lower California. A portion of an upper valve from beds of Pliocene age on Maria Madre Island, Mexico, may be referable to the present species.

Ostrea erici is not similar to any Recent west American species.

Ostrea vespertina Conrad
Plate 39, Figures 1-3, 5-9

Ostrea vespertina Conrad, Jour. Acad. Nat. Sci. Philadelphia, 2nd Ser., Vol. 2, Pt. 4, p. 300, 1854. [February, 1854, in table of contents. Also stated to have been presented at Academy meeting March 7, 1854 (see An Index to Sci. contents of the Journal and Proceedings of the Acad. Nat. Sci. Philadelphia, 1812-1912, p. IX, 1913).] — Conrad, House Doc. 129, Projected Vol. 3, 33rd Congress, 1st Session, pp. 7, 15, July, 1855. P. 7, "Colorado desert," p. 15, "Locality. — Carrizo Creek, Miocene." Reprint by Dall, U. S. G. S., Prof. Paper 59, p. 168, 1909. — Conrad, in Blake, U. S. Pac. Railroad Expl., Vol. 5, Pt. 2, p. 325, pl. 5, figs. 36, 37, 38, 1857. "Carrizo creek, Colorado desert. Miocene." — Conrad, in Emory, Rept. U. S. Boundary Surv., Vol. 1, Pt. 2, p. 160, pl. 17, figs. 1a-d, 1857. "Carrizo Creek, and near San Diego, California (Miocene)." — Heilprin, U. S. G. S., 4th Ann. Rept., p. 315, pl. 71, figs. 2, 3, 4, 1884. "Carrizo Creek, Colorado Desert." (Conrad). Pliocene (Gabb). — Schuchert, Dall, et al., U. S. Nat. Mus., Bull. 53, Pt. 1, p. 475, 1905. "Miocene. Carriso Creek, and near San Diego, California." — Arnold and Anderson, U. S. G. S., Bull. 322, pp. 59, 148, pl. 23, fig. 10, 1907. "One mile north of Schumann." "Fernando (Pliocene)." — Arnold, U. S. G. S., Bull. 396, p. 77, pl. 24, figs. 4, 5, 1909. "Upper Etchegoin formation; locality 4715." "Upper Miocene." [Pliocene.] P. 79, "Pacific Beach, Russ School, San Diego well, San Diego County (Henry Hemphill; W. H. Dall; Homer Hamlin; Delos and Ralph Arnold, and others)." "San Diego formation, lower Pliocene." — Arnold and Anderson, U. S. G. S., Bull. 398, pp. 129, 138, pl. 46, figs. 4, 5, 1910. [Same figures as in preceding reference.] — Hanna, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 18, p. 468, pl. 26, figs. 1, 2, 3, 1926. Coyote Mountain, Imperial Co., California, Pliocene. Also "San Diego," Pliocene. — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 428, 1926. "San Diego," Pliocene. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, pp. 84, 85, 1929. "San Diego Pliocene." — Woodring, U. S. G. S., Prof. Paper 190, p. 42, pl. 8, figs. 1, 2, 3, 4, 8, 9; pl. 9, fig. 5, 1938. [Lectotype, figs. 3 and 8. Figs. 1, 2, 4, 9, from Barrett's oil well, south side of Imperial Co., California, Pliocene. Plate 9 fig. 5, from Third Street tunnel, Los Angeles, California.] P. 44, localities near San Diego "Pliocene San Diego formation." — Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, table opp. p. 112, p. 113, 1941. "San Diego." "Pacific Beach." — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 59, 1944. "Near the intersection of Thirty-fourth and Tomkins Streets," San Diego, Pliocene. — Hertlein and Grant, Calif. State Div. Mines, Bull. 70, Chapt. 2, p. 60, 1954. San Diego Formation, Pliocene. — Emerson and Hertlein, Trans. San Diego Soc. Nat. Hist., Vol. 13, No. 17, p. 353, fig. 3 d-h (p. 356), 1964. Coyote Mountain, Imperial Co., California, Pliocene.

Type specimen. — Lectotype No. 4502, Academy of Natural Sciences of Philadelphia.

Type locality. — "Locality. Near San Diego, California. Dr. LeConte." "Miocene Species?"

Range. — Late Miocene (Nomland; Stanton); Pliocene.

Occurrence in San Diego Fm. — C.A.S. 1136, 1176, 1402, 1413, 28882, 28887, 28889, 28890, 28892, 34221, 36599. L.A.M. 107, 122, 124, 180, 302, 305, 305A, 309, 323, 208. S.D. 20, 37, 80, 331, 365, 408, 413, 446, 1142. U.C.L.A. 294, 296, 302, 310, 1382, 1383, 1385, 2420.

Original description. — Ovato-subfalcate, lower valve plicated or ribbed; hinge long and wide, sharp and somewhat pointed; ligament cavity wide, profound, minutely wrinkled; margins abrupt, cavity not very deep; muscular impressions large, impressed; upper valve flat, irregular; pallial impression crenulated throughout its whole extent, profoundly crenulated on the upper half of the shell. From beak to base 1 7/8; transversely 1 1/2. (Conrad.)

This species has a remarkable resemblance, externally, to a variety of *O. borealis.* The upper margin of the muscular impression is generally of a sigmoidal outline. (Conrad.)

Remarks. — Specimens of an oyster found in Pliocene strata at several localities in and near San Diego agree in all particulars with Conrad's original description of *Ostrea vespertina.* The lower valve is usually convex, bearing 5 to 10 plications, and the upper valve is flattish and fits down into the fluting around the margin. The margin below the ligamental area bears denticulations which sometimes occur along the margin for half the

length of the valve. Some of these specimens agree with illustrations of the upper valve selected by Woodring for the lectotype of this species.

Woodring, 1938, gave an extensive discussion of the problems concerned with the identification of *Ostrea vespertina*. Conrad originally gave the locality as "near San Diego," but some authorities consider it doubtful that Conrad's specimens came from this locality. Three years later (1857) he gave another description and illustrations and cited the species from "Carrizo Creek. Miocene." In another report the same year he described and illustrated specimens and gave the locality "Carrizo Creek, and near San Diego, California. (Miocene)."

Through the courtesy of Dr. Horace G. Richards, we were able to study the type lot of nine specimens of this species which are preserved in the Academy of Natural Sciences of Philadelphia. As mentioned by Woodring, the label does not bear the locality nor the name of the collector but the preservation is such as to indicate to him that they came from "evidently Carrizo Creek." This appears a reasonable conclusion. He illustrated only upper (right) valves but four lower (left) valves also are in the type lot. The lectotype selected by Woodring is a nearly flat upper valve, 37.7 mm long (slightly incomplete) and 48.6 mm high.

We also have studied a series of specimens from Loc. 33277A (CAS), collected by G D. Hanna from an oyster reef in Painted Gorge on the north side of Coyote Mountain, Imperial Co., California. These specimens agree exactly with Conrad's illustrations of 1857 (plate 5, figs. 36-38) and possess similar denticulations along the upper margins. This feature was not mentioned by Woodring as being present on the lectotype but such denticulations are visible in shell layers along the anterior edge of the dorsal margin of that specimen and they are present on others in the type lot. Denticles are present on some valves from San Diego only 2 mm high (beak to base). The muscle impressions are often somewhat extended upward along the posterior end. Some of these specimens are virtually indistinguishable from Recent specimens of *Ostrea palmula* Carpenter (517), described one year later from the Gulf of California. Perhaps the average Recent specimen has the upper margins a little more fluted and the excavation under the beak of the lower (left) valve a little deeper but these features are variable in a large series. In any case, the specific name *vespertina* is the earlier of the two.

The chief difference between specimens from the San Diego Formation and those from the Carrizo Creek region appears to be size. Some specimens from San Diego are 75 mm high and 55 mm long (more circular forms may be 65 mm long). We have used the name *Ostrea vespertina* for our specimens because many left valves agree in all conchological characters with the lectotype which bears the earliest name proposed for a fluted oyster with a flattish upper valve and denticulate margins from strata of Pliocene age in southern California.

Woodring (1938, p. 44; 1940, p. 92), pointed out that some weakly plicated or nearly smooth valves of *O. vespertina sequens* Arnold (518), described from beds of late Pliocene age in San Joaquin Valley, California, are not separable from elongate specimens of *O. lurida* Carpenter (519) which, he suggested, may be a modern representative of that subspecies. The group of species including *O. vespertina* and its subspecies *O. v. sequens*, *O. palmula*, *O. conchaphila* Carpenter (520) and *O. lurida* and its forms (521), have many shell characters in common and it appears reasonable to conclude that they represent a closely related group of species.

The large oyster from Imperial Co., California, named *Ostrea heermanni* by Conrad (522) has an ovate, flattish, very thick shell. The body cavity is fairly deep on the anterior side and the exterior flutings are reflected interiorly along the margins of rather thin valves, but not on thick valves. The growth lines are decidedly looped upward on each side of the ligamental area, distinctly different from those of *O. vespertina* which are but slightly or not at all looped upward.

Some authors have considered a close relationship to exist between *O. vespertina*, *O. haitensis* Sowerby, *O. heermanni* Conrad, and *O. wiedeyi* Hertlein. The latter three species bear a greater resemblance to *O. veatchii* Gabb and their similarities will be discussed in connection with that species. Studies of the type lot of *O. vespertina* and other specimens from the type locality, also the selection of a lectotype by Woodring, have furnished a basis for separating this species from typical *O. veatchii* with which it has been united by some authors.

Arnold (1909, p. 78) pointed out that "*O. vespertina* is smaller, relatively narrower, and usually more falcate in outline and carries plaits more regular in size and generally fewer in number than *O. haitensis*." Both Dall and Arnold pointed out that the west coast species closely resembles *O. sculpturata* Conrad (523) from the late Miocene and Pliocene of eastern United States. The illustrations of that species from Florida by Mansfield (524) are remarkably similar to some specimens of *O. vespertina* from the San Diego Formation. A subspecies, *Ostrea vespertina venezuelana* Weisbord (525), described from strata of Pliocene age in Venezuela, is very similar to some forms of *O. vespertina* from southern California.

The record of *Ostrea vespertina* cited as occurring in the Miocene of Ceylon by Deraniyagala (526) obviously is referable to *O. virleti* or one of that group. The species cited by Masson and Alencaster Ibarra (527) as "*Ostrea sp.* cf. *O. vespertina* Conrad" from Miocene beds of San Andres Tuxtela in the State of Vera Cruz, Mexico, is referable to one of the east American species. The record of "*Ostrea* cfr. *vespertina* Conr." cited by Khomenko (528) from beds of Miocene age in Kamtschatka, evidently is referable to some other species. Conrad's species was not cited by Slodkewitsch, 1938, in his comprehensive work on the late Tertiary fauna of that region.

Ostrea vespertina has been cited as occurring in beds of late Miocene age in central California and in the San Joaquin valley (529), but we have not seen specimens certainly referable to this species from strata of that age.

This species has been recorded as occurring in strata of Pliocene age as far north as the San Benito and San Juan Bautista quadrangles in California. It has been reported from beds of that age in southern California, Lower California, and south to Maria Madre Island, Mexico.

Ostrea veatchii Gabb
Plate 39, Figure 4;
Plate 40, Figures 1, 4, 5, 6

O[strea]. veatchii Gabb, Geol. Surv. Calif., Palaeo., Vol.

2, p. 34, pl. 11, fig. 59, 1866. — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11, "San Diego," p. 29, "about ten miles northward from San Diego," 1878. — Heilprin, in White, U. S. G. S., Fourth Ann. Rept., p. 316, pl. 72, fig. 1, 1884. (Copy of Gabb's illustration). — [?] Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 63, 1903 (as *"Ostrea veatchi?"*). "Pacific Beach" and "Russ School", San Diego, Pliocene. — Arnold, U. S. G. S., Prof. Paper 47, p. 28, 1906. "San Diego Formation".— Arnold, in Eldridge and Arnold, U. S. G. S., Bull. 309, p. 250, pl. 39, fig. 1, 1907. "Lower Pliocene, San Diego."

Ostrea vespertina Conrad, E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, pp. 417, 428-429, 1926 (in part). "San Diego", also Cedros Island, Bahía Tortólo (Turtle Bay), and near Elephant Mesa, Lower California, Pliocene.

Not *Ostrea vespertina* Conrad, 1874.

Ostrea haitensis Sowerby subsp. *vespertina* Conrad, Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 128, pl. 14, fig. 4, 1930. "The holotype of *O. veatchii* is figured."

Type specimen. — No. 4502, Academy of Natural Sciences of Philadelphia.

Type locality. — "Cerros Island, associated with *Pecten Veatchii, P. cerrosensis*, and the following species [*O. cerrosensis* Gabb]. Dr. J. A. Veatch."

Range. — Middle Pliocene, from San Diego, California, to Bahía Tortólo (Turtle Bay) and Cedros Island, Lower California.

Occurrence in San Diego Fm. — S.D. 6307.

Original description. — Shell large, subequivalve, varying from nearly equilateral to very oblique, the obliquity being always to the left side. Surface marked by ten or a dozen large, angular, radiating ribs, some of which arise at or near the beaks, the others branching from the first, or interpolated between them; the interspaces are angular, and the ribs are marked by more or less squamose plates, and occasionally these plates assume almost the character of spines; internally the ribs show only towards the margins. Hinge short, very broad and shallow; no crenulations or denticulations near the margin. Muscular scar large, suboval to subquadrate. (Gabb.)

Remarks. — Two valves from Pacific Beach agree with the form described as *Ostrea veatchii* Gabb. The largest of these is 125 mm long. The valves are deeply and sharply fluted and some of the flutings develop extensions into spines. Specimens such as these have been considered by several authors to be variants of *O. vespertina*.

Through the courtesy of Dr. Horace G. Richards, Academy of Natural Sciences of Philadelphia, we have been able to examine the type lot of *Ostrea veatchii*. The type is a comparatively thin (about 4 mm) lower valve, 75 mm high and 68 mm long, the upper anterior margin incomplete. The exterior is sculptured with about 10 angular, radiating ribs which at intervals develop into spines. Interiorly there is no recessed area under the hinge, the muscle impression is fairly large and rounded, and as mentioned by Gabb, there are no denticles along the margin of the valve. An upper valve, about the same size, gently convex, sculptured similar to the type, is in the type lot.

The gently arched upper valve, more numerous, spinose ribs which deeply interlock along the ventral margin and the smooth margins totally lacking denticles are shell characters quite different from those of *O. vespertina* from its type locality. Some of the tubular spines on a specimen from Cedros Island in the collections of the Los Angeles County Museum (A. 6573.54-2) are 28 mm long (see pl. 40, fig. 5). The shell of typical specimens is lamellar with irregular open spaces between the lamellae. Dr. Hendryk B. Stenzel mentioned to us that this kind of shell structure is similar to that of some members of the *Ostrea hyotis* group. We restrict the usage of the name *O. veatchii* to specimens agreeing in general shell characters with the type specimen. Among Recent west American oysters, the presence or lack of denticles along the margin below the hinge is a rather constant character.

Examination of about 50 specimens from Pliocene strata on Cedros Island, the type locality of *O. veatchii*, and of additional specimens from Bahía Tortólo (Turtle Bay), Lower California, reveals considerable variation. Some of these agree exactly with Gabb's type and lack denticles on the margin. Others, usually smaller, more trigonal or falcate forms have very fine denticulation only along the upper portion of the margin, others have denticulation similar to that on *O. vespertina*. Also occurring at Cedros Island are specimens agreeing in every way with *O. angelica*. The variation in this series from Cedros Island is such as might lead one to question whether perhaps some of these are hybrids between *O. veatchii and O. angelica*. For the present we believe it desirable to retain *O. veatchii* as a separate taxon at least until the relationships of west American oysters are better known.

Exteriorly some specimens of *O. angelica* bear a close resemblance to *O. veatchii* and that probably explains Dall's (530) citation of the latter as occurring Recent in the Gulf of California. The shell of *O. angelica* is usually thicker, the flutings usually do not extend to the dorsal third of the valves and do not develop into spines, interiorly the margins below the ligamental pit are finely denticulate, and the muscular impression is semicircular in outline.

A large rounded, thick (40 mm at thickest), flattish valve illustrated by Gabb (1869, pl. 17, figs. 21, 21a; Heilprin, 1884, pl. 72, fig. 1) under the name of *Ostrea veatchii*, which accompanied the type lot of *O. veatchii*, is 123 mm long, 131 mm high, maximum thickness about 42 mm. It closely resembles specimens of *O. heermanni*. In the text (pp. 60, 61) following the caption to the figures of this specimen, Gabb mentioned the occurrence of thick, flat oysters from the east coast of Lower California. It seems probable that the valve discussed here came from that region.

Ostrea wiedeyi Hertlein (531) described from early Miocene strata on Santa Rosa Island, California, bears a strong resemblance exteriorly to *O. veatchii*. The shell of this Miocene species is much thicker and on some specimens the growth lines loop upward to some extent on each side of the ligamental area. Another feature noticed on the interior of these fossils is the presence of a depression just below the hinge on the posterior side of the body cavity.

Loel and Corey (532) considered *O. wiedeyi* to be identical with *O. loeli* Hertlein which they placed as a variety of *O. vespertina*. The thick shell, shape of body cavity, and muscle impression, as well as the shape of the

hinge line of *O. wiedeyi* bear a greater resemblance to *O. heermanni* than to typical *O. vespertina*. *Ostrea wiedeyi* bears a close resemblance to *Ostrea haitensis* Sowerby as illustrated by Maury (533) from the late Miocene of Trinidad but the west coast species differs in lacking the transverse vermiculate threads on the margin below the hinge.

Ostrea veatchii, at times, has been placed in the synonymy of *O. haitensis* Sowerby (534), a species occurring in strata of Miocene age in the Caribbean region. The west American shell represents a similar but distinct species with a thinner shell and without denticles or transverse threads on the margin. The *Ostrea haitensis* group includes species such as *O. gatunensis* Brown and Pilsbry described from beds of Miocene age in the Panama Canal Zone and perhaps in a general way includes west American fossil forms such as *O. wiedeyi* Hertlein, *O. loeli* Hertlein and *O. howelli* Wiedey. *Ostrea haitensis* closely resembles *O. virleti* Deshayes, a large plicated oyster which occurs in strata of late Tertiary age in the Mediterranean and Indian Ocean regions. The distribution of *O. virleti* was discussed by Davies (535) and its relationships by Cox (536).

We are uncertain what species is represented by Dall's record (537) of *Ostrea veatchii* from late Tertiary beds on Atka Island and Unga Island, Alaska. The same can be said for the records of *O. veatchii* from Miocene strata in western Washington cited by Weaver (538). *Ostrea fisheri* Dall (539), a large round form, living in the Gulf of California and known from Pliocene to Recent in that region, is believed to be closely related to *O. hyotis* Linneaus, an Indo-Pacific species and to *O. thomasi* McLean which lives in Floridan waters.

SUBGENUS *AGEROSTREA* VIALOV

Agerostrea Vialov, Acad. Sci. URSS, Compt. Rend. (Doklady), Nouv. Sér., Vol. 4 (13), No. 1 (105), p. 20, 1936. — Stenzel, Jour. Paleo., Vol. 21, No. 2, p. 168, 1947.

Type species (by original designation). — "type: *A. ungulata* Schloth." [= *Ostracites ungulatus* Schlottheim Taschenbuch f. Mineralogie herausgegeben von C. C. Leonhard, Jahrg. 7, Abt. 1, p. 112, 1813. Ref. to "Knorr P. II. T. D. Vii. F. 3 und 6. Petersberg." Illustrated by Coquand, Monographie du genre *Ostrea*. Terrain Crétacé (Marseille), p. 58, Atlas, pl. 31, figs. 4-15, 1869. — Carter, Palaeontology, Vol. 11, Pt. 3, p. 463, pl. 85, figs. 2,3; pl. 86, fig. 6; pl. 87, fig. 8, 1968.]

Range. — Late Cretaceous to Recent.

Original description. — Coquille longue, étroite, incurvée, avec une surface médiane lisse. (Vialov.)

Remarks. — Many supraspecific group names have been proposed in the Ostreidae. Some authors have placed *Ostrea megodon* in the subgenus *Lopha* Roding in Bolten (540) which has as type *O. crista-galli* Linnaeus, a Recent species. Recently, Dr. H. B. Stenzel suggested (pers. comm.) that *O. megodon* could be placed in *Agerostrea* Vialov which was based upon a species originally described from beds of Maestrichtian, late Cretaceous age. We have not seen specimens of the type species of *Agerostrea* but some of the illustrations referred to *O. ungulata* by Coquand (see especially his pl. 31, figs. 6, 7, 8) closely resemble *O. megodon* in general shape and shell characters.

Many species, especially of Jurassic and Cretaceous age, have been assigned to *Lopha*, as have others in the Cenozoic. Recent species of that genus occur in shallow tropical and subtropical marine waters.

There is no agreement among authors as to which, if any, Mesozoic species should be assigned to *Lopha*. Gillet (541), following Douvillé, considered typical "*Alectryonia*" Fischer de Waldheim (type, *Ostrea crista-galli* Linnaeus) [= *Lopha*] to predominate from late Cretaceous to Recent.

Beginning in middle Jurassic a group of oysters developed which were predominant during late Jurassic and early and middle Cretaceous. These are arcuate in outline with long, narrow beaks and numerous extremely angular plicated margins and they are less equilateral in form than *Lopha*. The genus *Arctostrea* Perivinquiére (542) was proposed for these with the type species *Ostrea carinata* Lamarck. Some authors have placed *Arctostrea* in the synonymy of *Lopha* but these taxa represent quite distinct supraspecific units.

The name *Rastellum* Schröter, 1782, was discussed and rejected by Stenzel (1947, pp. 181-182). The history of *Rastellum* as a genus name is rather involved but usage of it by authors subsequent to Schröter is much later than the name *Lopha*.

Ostrea (Agerostrea) megodon Hanley
Plate 38, Figures 1, 5, 7

Ostrea megodon Hanley, Proc. Zool. Soc. London, Pt. 13, for 1845, p. 106 (issued February, 1846). — Sowerby, Conch. Icon., Vol. 18, *Ostraea*, species 24, pl. 12, figs. 24a, 24b, 1871. "Peru." — E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 427, pl. 28, fig. 1, 1926. "Pliocene beds at Bernstein's abalone camp on southeast side of Cedros Island. Pliocene." Also other localities.

Ostraea gallus Valenciennes, Zool. Voy. Venus, pl. 21, figs. 1, a-d, 1846. [No description.]

Ostrea cerrosensis Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 35, pl. 11, fig. 61, 1866. "with the preceding species". [That is, *Ostrea veatchii* Gabb from "Cerros Island, associated with *Pecten Veatchii*; *P. cerrosensis*, and the following species."]

Ostrea megadon Hanley subsp. *cerrosensis* Gabb, Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 130, pl. 14, fig. 1, 1930. [One of Gabb's type specimens illustrated as a lectotype.]

Ostrea (Lopha) megodon Hanley, Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 66, fig. 123 (Scammon's Lagoon), 1958. Scammon's Lagoon, Lower California, to Paita, Peru, Recent.

Ostrea (Alectryonia) megodon Hanley, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 172, pl. 23, figs. 3, 3a ("Bayovar, Peru"), 1961. Gulf of California to northern Peru, Recent. — Olsson, Neogene Mollusks from Northwestern Ecuador (Paleo. Res. Inst.: Ithaca, New York), p. 39, pl. 1, figs. 1-1b (Punta Gorda, Ecuador, Pliocene), 1c (Quebrada Mellisa, Burica Peninsula, Panama, Pliocene), 1964.

Type specimen: British Museum (Natural History).

Type locality. — "Hab. Peru (Cuming). Mus. Cuming."

Range. — Pliocene to Recent. Recent from Scammon's Lagoon, west coast of Lower California, Mexico, to San Felipe and Puerto Peñasco in the Gulf of California and south to Paita, Peru, in 15 meters (8 fathoms) to 112 meters (61 fathoms).

Occurrence in San Diego Fm. — S.D. 6307. U.C.L.A. 2420.

Original description. — Ost. Testâ falcatâ, glabrâ, solidâ, subaequivalvi, pallidè livido-purpurascente, margines versùs plicatâ; plicis anticis 5 aut 6, maximis, subangulatis; posticis minimis, angulatis, paucis, subobsoletis; margine valde plicato, intusque magis minusve scabro; natibus incurvatis; superficie internâ albo-virescente, nunquam margaritaceâ; cicatrice satis magnâ, reniformi. Long. 5 poll. (Hanley.)

Remarks. — Two small specimens of *Ostrea megodon* are present in the collections from Pacific Beach. One from Loc. 6307 (SD) is 42.3 mm long and 29.3 mm wide. The other specimen, from Loc. 2420 (UCLA), is 39.6 mm long (beak to base), 21 mm wide, convexity (not including flutings), 12 mm. These specimens, except in size, agree in all observable shell characters with Recent specimens of *O. megodon* from tropical west American waters, in shape, muscle impressions, and denticulated dorsal margins. There is variation in the development of denticulation on Recent specimens of this species. On some, denticles occur along the margin for about one half the distance from the beak to the ventral margin, on others these are well developed below the beak but soon become weaker ventrally.

The measurement of the type specimen of *Ostrea megodon* given as "5 poll" is equivalent to approximately 126.6 mm. The largest Recent specimen in the Academy's collection is a left valve collected by Don Frizzell at Brazo Ramon estuary, south of Sechura, Peru. It is 107 mm long (beak to base). A Recent specimen from Bahía Tortólo (Turtle Bay), Lower California, is 78 mm long (beak to base), 40 mm wide, the convexity (not including flutings), 19.5 mm. Galtsoff (543) mentioned that specimens of this species in Panama attain a length of 15-16 cm, but this appears to be an exceptional size. Olsson (1961; 1964) has discussed Recent and fossil specimens of this species from northwestern South America and Panama.

The name *Ostrea gallus* Valenciennes, 1846, accompanied illustrations of a fluted oyster but was not accompanied by a description. The illustrations obviously appear to be referable to *O. megodon* and this interpretation has been accepted by most authors.

Gabb in 1869 described *Ostrea cerrosensis* from strata of Pliocene age on Cedros Island, Lower California. Stewart later discussed and illustrated one of Gabb's type specimens and placed it as a subspecies of *O. megodon*. The reason for retaining *O. cerrosensis* as a subspecies was based upon the difference in size between the type specimens of *O. megodon* and *O. cerrosensis*. The illustration given by Gabb, said to be natural size, is approximately 59 mm long. The dimensions of the specimen illustrated by Stewart as lectotype of *O. megodon cerrosensis* were given as 53 mm long, 66 mm high, convexity (not including flutings), 15 mm.

A specimen of *Ostrea megodon* collected by E. K. Jordan from strata of Pliocene age on Cedros Island is 79 mm long (beak to base) and a larger specimen collected from the same general area by Mrs. Joyce Roderick is 101 mm long (beak to base). Specimens from beds of Pliocene age in Ventura County, Loc. 90 (CAS), are 99 mm long. All these specimens, although not so large as the type specimen of *O. megodon*, agree with that species in all observable shell characters. We therefore place *O. cerrosensis* Gabb in the synonymy of Hanley's species, as did Dall.

Woodring, Bramlette, and Kew (544), assigned the subspecific name *Ostrea megodon cerrosensis* to an oyster with broad shallow plications from late Pleistocene beds in the Palos Verdes Hills in Los Angeles Co. The degree of width and depth of fluting varies in a series of Recent specimens from tropical west American waters and therefore we are inclined to consider as referable to *O. megodon* those fossil specimens which differ from Recent ones only in the degree of fluting. Large Recent specimens have 5 to 6 rounded well developed flutings along the anterior margin. The exterior is colored greenish and purple, and the interior whitish and green.

Ostrea megodon has been recorded from beds of late Tertiary age in the Caribbean region but most of those records are now referred to closely related forms which have been described as separate species.

Ostrea paramegodon Woodring (545) from the Bowden beds of late Miocene age in Jamaica, was described as smaller, less curved and with shallower folds than *O. megodon*. Woodring stated that except for size, the fossil from the Gurabo Formation, Miocene, in the Dominican Republic, illustrated by Maury (546), greatly resembles the west American *O. megodon*.

The species cited by Olsson (547) under the name of *O. megodon* from Miocene strata in Costa Rica, was later placed in the synonymy of *O. messor* Maury (548) which was described from strata of late Miocene age in Trinidad. Maury also described *O. messor* var. *caimita* and *O. messor* var. *tabiquita*. A subspecies from the Miocene of Columbia was described by Weisbord in 1929 as *O. messor colombiensis*. We have examined specimens from Miocene beds in Columbia identified by Anderson (549) as *O. "megadon"*. These are smaller and less curved in outline than most Recent shells of this species which we have observed.

Undoubtedly a number of forms from strata of late Tertiary age in the Caribbean region and the west American *O. megodon* form a closely related group. The fossil forms vary somewhat in size, curvature and magnitude of flutings. Just how many of these should retain separate specific or subspecific designation is open to question. Weisbord (550) recently discussed several members of this group.

SUPERFAMILY ANOMIACEA RAFINESQUE (551)
FAMILY ANOMIIDAE RAFINESQUE (552)

Shell large or small, generally irregular and distorted, attached by close contact to various objects by means of a calcified byssal plug passing through a round hole or foramen in the umbone of the right valve, remaining attached throughout life or only in the early stages. Valves rounded or subcircular, variously inflated, but generally more or less irregular because of fixation, nac-

reous, and often with a platy or micaceous texture, thin or heavy. Hinge edentulous but sometimes provided with large, divergent resilial processes or crura simulating hinge teeth. Ligament internal, attached to resilial processes along the hinge margin or to deep scars. Interior of the left valve has two or three rounded or elongated scars which represent the attachment impressions of the byssal and retractor muscles. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 175, 1961). Jurassic to Recent.

The members of the Anomiidae live between tides or in comparatively shallow water attached to other shells or to rocks.

This family is represented in the San Diego Formation by two genera.

Key to Genera of Anomiidae

A. Upper valve with one large and one small muscle impression . . . . . *Pododesmus*

B. Upper valve with one large and two small muscle impressions. . . . . *Anomia*

GENUS *ANOMIA* LINNAEUS

Anomia Linnaeus, Syst. Nat., ed. 10, p. 700, 1758. Numerous species cited including *Anomia ephippium*. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, pp. 774, 781, April, 1898. "Type *A. ephippium* Linné." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 240, 1931. Type (as indicated by Children, 1823): *Anomia ephippium* Linnaeus.

Type species (designated by Schmidt, Versuch der Conchylien-Sammlung, pp. 71, 177, 1818). — "Typ. *Anomia ephippium*" [Linnaeus]. [*Anomia ephippium* Linnaeus, Syst. Nat., ed. 10, p. 701, 1758. "Habitat in M. Mediterraneo & America." Illustrated by Chemnitz, Syst. Conchyl. Cab., Bd. 8, p. 81, pl. 76, figs. 692, 693, 1785. Cited from "Mittelländischen See", also "Ostund Westindischen Meeren." See discussion of this species by Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 198-199, 1952. "The form to which Linnaeus gave the name *ephippium* is that common on the west coast of France."]

Range. — Jurassic to Recent. Recent cosmopolitan, except in Arctic and Antarctic. From the intertidal zone to 3001 meters (1094 fathoms). Usually in intertidal or shallow water.

Description. — Shell subrounded or irregular in outline, rather thin, attached with a calcified byssal plug which passes through a sinus in the right valve; left (upper) valve with one large and two smaller muscle impressions; hinge edentulous.

Remarks. — Five species of *Anomia* have been reported from Cenozoic strata of California, one of which occurs in the San Diego Formation. One Recent species lives in west American waters between San Pedro, California, and Paita, Peru. In tropical and subtropical waters it is accompanied by one or possibly two species of *Anomia*, whose systematic status is doubtful.

The exterior of valves of *Anomia* may be smooth or with radial ribs which on the upper valve sometimes are spinose. Merrill (553) discussed the variation in sculpture of *Anomia aculeata* Gmelin, an east American species.

The species of this genus are attached to rocks, shells, or other objects and often acquire sculpture corresponding to that of the object to which they are attached. Often only upper valves are found on the beach, or as fossils, because those become loose and are washed away, whereas the lower valve remains attached.

Boulenger (554) mentioned that the byssal plug of members of this genus apparently corrodes surfaces to which it is attached and as a result the shell often lies sunk into a pit of its own making.

The Recent species of *Anomia* in Great Britain have received special study by Winckworth (555). Loosanoff (556) discussed the metamorphosis of the east American *A. simplex* d'Orbigny.

Anomia peruviana d'Orbigny
Plate 40, Figure 2; Plate 41, Figure 8

Anomia peruviana d'Orbigny, Voy. dans l'Amér. Mérid., Vol. 5, Pt. 3, p. 673, 1846. — Phillippi, Abbild. u. Beschreib. Conchyl., Bd. 3, No. 8, p. 131 (1), *Anomia*, pl. 1, figs. 2, 3, 1850. "Patria: Peru," Recent. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 240, pl. 12, figs. 2, 5, 1931. Various localities cited, Pliocene to Recent. — Hertlein and Strong, Bull. Amer. Mus. Nat. Hist., Vol. 107, Art. 2, p. 177, 1955. "Pinas Bay, Panama." Recent. Also earlier records. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 80, fig. 152, 1958. Monterey, California, to Paita, Peru. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 177, pl. 24, figs. 2-2f, 1961. Lower California to northern Peru.

Type specimen. — British Museum (Natural History).

Type locality. — "aux environs de Payta (Pérou)."

Range. — Late Miocene or early Pliocene (in Ecuador, Olsson) to Recent. Recent from San Pedro California, to Punta Peñasco in the Gulf of California and south to Paita, Peru, and the Galápagos Islands, from low tide to 110 meters (60 fathoms) on rocks or on shells.

Occurrence in San Diego Fm. — C.A.S. 1137, 1400, 1413. L.A.M. 305, 305A, 305C.

Original description. — Coquille presque arrondie, un peu carrée, plus longue que large, très-déprimée, marquée en dessus de quelques indices de côtes rayonmantes peu prononcées, nombreuses. Sa couleur est verdâtre très-pâle ou rosée; son intérieur est verdâtre, le ligament entièrement vert. La valve inférieure a ses bords désunis sur une grande largeur. Diamètre, 33 millimètres. (d'Orbigny.)

Remarks. — Three upper valves of an *Anomia* are present in the Academy's collections from Pliocene strata at San Diego. The largest one, 36.6 mm from beak to base, is smooth but the other two bear radial ribs. These shells are so similar to Recent specimens of *Anomia peruviana* that there appears to be no reason to doubt their identity. A few small valves referable to this species are in the collections of the Los Angeles County Museum from Locs. 305, 305A and 305C (LAM).

Seven left (upper) valves in the collections of the

Los Angeles County Museum, the largest one 59 mm high, were collected by Charles Sternberg at Pacific Beach. According to the label these were from beds of Pliocene age. The excellent preservation of the specimens as well as the softness of the matrix leads us to question whether these valves may have been collected from beds of Pleistocene age which overlie the Pliocene strata at Pacific Beach.

Recent specimens of *Anomia peruviana* vary in shape and in sculpture. They may be smooth exteriorly or they may bear well developed radial ribs occasionally bearing very short spines. Exterior sculpture of the shell of *Anomia* may simulate that of the object to which it is attached. Partly because of the multiplicity of forms resulting from such situs this species has received a number of names in the literature. The following are generally considered to be synonyms: *Anomia hamillus* Gray, *A. larbas* Gray, *A. alectus* Gray, *A. lampe* Gray, *A. pacilus* Gray, *"Anomya" simplex* Mabille.

Anomia fidenas Gray has been considered to be a synonym of *A. peruviana* by many authors but Olsson (557) recently accorded it specific status.

Anomia adamas Gray (558), originally described from the Galápagos Islands and Lord Hood's Island, was said by E. K. Jordan (559) to differ from *A. peruviana* in that the two distal muscle impressions of the upper valve are equidistant from the umbo rather than nearly in a straight line. It might be questionable whether or not this criterion can be relied upon consistently to separate the two species. Keen (1958, p. 80) considered *A. adamas* to be a valid species, a distinction based chiefly on a radial ribbing pattern on some specimens. A problem in connection with *A. adamas* is the locality record "Lord Hood's Island." There is a "Hood Island" in the Galápagos group and "Lord Hood Island" in the Gambier Island group. Several authors (560 have cited this species as occurring in the southwestern Pacific. Whether it occurs in both west American and western Pacific Islands is open to question.

Anomia limatula Dall was based upon large smooth valves presumably from beds of Pleistocene age at Pacific Beach. It is probably not more than subspecifically different from *A. peruviana* and some authors consider them to be identical.

Anomia subcostata Conrad was originally described from beds now believed to be of Pliocene age, in Imperial Co., California. Hanna (561) mentioned the great variation in a series of specimens and suggested that it is quite possible that Conrad's species may not be separable from some of the Recent west American species.

Anomia peruviana has been reported from strata of middle Pliocene age at Bahía Tórtola (Turtle Bay), Lower California and from deposits of Pleistocene age from southern California to Peru. At the present time it lives in quiet bays where it is attached to rocks or to empty shells by a byssus which extends through a notch in the lower valve. The pearly upper valves, which may be white, green or yellow, are often found upon the beaches where the species occurs. The lower valves often are not found, or occur but sparsely among empty shells. This is probably a result of the method of attachment.

Anomia limatula Dall

Anomia limatula Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 15, July 1, 1878. — Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 27, 28, 1878. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 785, pl. 35, fig. 19, April, 1898. "Pacific Beach near San Diego, Stearns." "Pliocene." Also other localities, Pliocene and Pleistocene. — Schuchert, Dall, et al., U. S. Nat. Mus., Bull. 53, Pt. 1, p. 50, 1905. "Pliocene. San Diego, California."

Type specimen. — "Holotype" No. 7949, United States National Museum. ["Plesiotypes" No. 154341 United States National Museum (Schuchert, Dall, et al.). Specimens labeled "Original lot" by Henry Hemphill are Nos. 695, 695a, b, c, California Academy of Sciences Department of Geology type collection.]

Type locality. — "late Tertiary deposits of the Californian coast," San Diego. [Cited later (1878, p. 27) from "Strata of the San Diego Peninsula," also "strata on the mainland" "To the eastward of the town, or what is known locally as the 'railroad land'."]

Range. — Pleistocene.

Remarks. — Four upper (left) valves of *Anomia limatula* labeled by Henry Hemphill "Original lot" from "Foot of 30th street" in San Diego are in the collections of the California Academy of Sciences. These evidently came from beds of Pleistocene age. Schuchert, Dall, et al., cited the age of the "Holotype" as "Pliocene" but there is no evidence that it came from beds of that age. Dall (1898) illustrated a specimen collected by Stearns at Pacific Beach and cited the age as Pliocene. The valve illustrated by Dall appears to be identical with those collected by Hemphill.

The species which Dall (1878, pp. 27, 28) listed with *Anomia limatula* indicate Pleistocene age for that assemblage and Arnold (562) later cited it as occurring only in deposits of that age. We know of no evidence indicating that *Anomia limatula* occurs in the San Diego Formation.

GENUS *PODODESMUS* PHILIPPI

Pododesmus Philippi, Wiegmann's Archiv f. Naturgesch. for 1837, Jahrg. 3, Bd. 1, p. 385. Sole species: *Pododesmus decipiens* Philippi. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, pp. 770, 774, 1898. Type: *P. rudis* Broderip. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1 p. 241, 1931. Type (by monotypy): *P. decipiens* Philippi = *Placunanomia rudis* Broderip, Cuba.

Type species (by monotypy). — *Pododesmus decipiens* Philippi, 1837, p. 386, pl. 9, figs. 1a, 1b, 1c, 1d. "Havana." [= *Placunanomia rudis* Broderip, 1834, illustrated by Reeve, Conch. Icon., Vol. 11, *Placunanomia*, sp. 2, pl. 1, figs. 2a, 2b, August, 1859. "Hab. West Indies; Broderip. Havana; Philippi." Also, Abbott, American Seashells (Van Nostrand Co., Inc.: New York), p. 372, pl. 38, fig. b, 1954. — Olsson and Petit, Bull. Amer. Paleo., Vol. 47, No. 217, p. 529, pl. 77, fig. 1, 1964. Key West, Florida, Recent.]

Range. — ?Eocene; late Oligocene, or early Miocene to Recent. Recent from the intertidal zone to about 73 meters (40 fathoms), occasionally deeper.

Description. — Valves rounded, radiately grooved or wrinkle-ribbed (but not plicated); lower (right) valve with an open or sometimes nearly closed byssal foramen;

upper (left) valve with one striated byssal impression and one muscle impression.

The crurum on the lower valve of the type species of *Pododesmus* (described by Olsson and Petit) has "a single crural process which arises as a ridge along the posterior side of the central chalky area and at the dorsal margin becomes enlarged into a prominent knob, its dorsal face folded or bilobate in shape and carrying the attachment scar of the ligament".

Remarks. — This genus differs from *Placunanomia* in possessing an open byssal foramen in the lower valve, although small or sealed over in the type species (563), and in lacking large, well developed cardinal crura. It, differs from *Anomia* in possessing only one muscle impression (in addition to the byssal impression), rather than two.

Knowledge of the generic and subgeneric assignment of fossil specimens is often doubtful where the preservation is imperfect.

Beu (Trans. Roy. Soc. New Zealand, Zool., Vol. 9, No. 18, p. 228, 1967) recently placed *Placunanomia*, *Pododesmus* and *Monia* in a new subfamily Placunanomiinae.

Species referred to *Pododesmus* were described by von Ihering (564) from the lower Patagonian beds, believed to be of Eocene age, in Patagonia. The muscle impressions on those fossils were imperfectly preserved and confirmation of the generic assignment is desirable. Soot-Ryen described *Pododesmus puntarenensis* (565) from beds of Tertiary age at Punta Arenas, Chile.

Key to Subgenera of *Pododesmus*

A. Lower valve with a small (sometimes nearly closed) foramen . . . . . *Pododesmus s. s.*

B. Lower valve with a large open foramen . . . . . *Monia*

SUBGENUS *MONIA* GRAY

Monia Gray, Proc. Zool. Soc. London for 1849, p. 121, issued between January and June, 1850. Several species cited including *Placunanomia macrochisma* Broderip, *P. cepio* Broderip, *P. alope* Broderip, *P. patelliformis* Linnaeus, *P. zealandica* Gray, *P. ione* Gray, *P. colon* Gray. — Beu, Trans. Roy. Soc. New Zealand, Zool., Vol. 9, No. 18, p. 229, November 2, 1967. Type as designated by Kobelt.

Type species (designated by Kobelt, Illustr. Conchylienbuch, Bd. 2, p. 376, 1881). — "Typus ist *Placunanomia zealandica.* Quoy (Taf. 112 fig. 4) von Neuseeland." [*Anomia zealandica* Gray in Dieffenbach's Travels in New Zealand, Vol. 2, p. 261, 1843. New Zealand. Illustrated by Reeve, Conch. Icon., Vol. 11, *Placunanomia*, sp. 4, pl. 1, fig. 4, 1859. New Zealand. — Suter, Man. New Zealand Moll., p. 845, pl. 56, figs. 1, 1a, 1913. — Beu, 1967, fig. 2e, f.]

Range. — Late Oligocene or early Miocene to Recent.

Description. — The shell of this subgenus differs from *Pododesmus s. s.* in possessing a large byssal opening and in that the large perforation of the lower valve only slightly embraces the large thin plug.

Beu (1967, p. 229) pointed out that the resilial crurum on the type species of *Monia* is single and with only a dorsal resilial surface. The interior in many of the Recent species is usually greenish or brownish in coloration.

Remarks. — *Monia* is reported to occur in western North America and Japan from late Oligocene or early Miocene to Recent, in Europe from Miocene to Recent, in England, Pliocene to Recent. It is living in New Zealand and Australia and probably occurs in strata of late Tertiary age in that region.

According to Keen (566) the species described as *Placunanomia inornata* by Gabb from beds of Eocene age in California, and later assigned to *Monia* by Vokes (567), is an *Anomia.*

Hayami (568) recently referred two species of early Cretaceous age in Japan to *Monia.* The muscle impressions of the species were not seen and therefore this record of *Monia* in the Cretaceous needs confirmation.

Pododesmus (Monia) macrochisma Deshayes
Plate 40, Figure 3; Plate 41, Figures 9, 12, 13

Anomia macrochisma Deshayes, Rev. Zool., Soc. Cuvierienne, December, 1839, p. 359. — Deshayes, Guerin's Mag. de Zool., 1841, pl. 34. — Philippi, Abbild. u. Beschreib. Conchyl., Bd. 3, Heft 8, *Anomia*, p. 132 (2), pl. 1, fig. 4, November, 1850 (as *Anomia macroschisma).* "Patria: Mare glaciale ad Kamtschatka, Insulas Aleutas, et sinus Ochotensis."

Placunanomia macroschisma Deshayes, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "well at San Diego." "Pliocene." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. "well-digging in stratum B^2," San Diego well. — Cooper, Seventh Ann. Rept. Calif. State Mineral., p. 260, 1888. "Pl. — San Diego well." — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, August, 1889. Dall's record (1874) cited. — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) cited.

Pododesmus (Monia) macroschisma Deshayes, Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 780, April, 1898. "Pliocene of San Diego, California, Hemphill." "Pliocene of the San Diego well." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 117, 1903. "Pliocene. — San Diego well (Dall)." — Waterfall, Univ. Calif. Publ., Bull. Dept. Geol. Sci., Vol. 18, No. 3, table opp. p. 78, 1928. "San Diego Pliocene."

Pododesmus macroschisma Deshayes, Arnold, U. S. G. S., Prof. Paper 47, p. 28, 1906. "San Diego formation . . . at Pacific Beach, north of San Diego." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 65, pl. 26, figs. 1a, 1b, (Recent), 1924. "Pliocene of San Diego." — Carson, Pan-Amer. Geol., Vol. 43, No. 4, p. 268, 1925. "San Diego fauna." Pliocene. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 242, 1931. "San Diego well, Balboa Park, San Diego (Dall, 1874)."

Monia macroschisma Deshayes, J. P. Smith, Proc. Calif.

Acad. Sci., Ser. 4, Vol. 3, p. 181, 1912. "San Diego-Purisima." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 151, 1919. "San Diego" Pliocene.

Pododesmus macroschismus Deshayes, Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) cited.

Type specimen. — Location unknown to the present authors.

Type locality. — "Kamtschatka." Recent.

Range. — Miocene to Recent. Recent from the Bering Sea to Cape San Lucas, Lower Caliofrnia, and Santa Inez Bay in the Gulf of Caliofrnia. From intertidal zone to 73 meters (40 fathoms). Also Miocene to Recent in Japan (569); Recent from Lat. 38° to 46°N., in Japan Sea, and 39° to 47° N. in Pacific. Kamtschatka (570), Pliocene to Recent.

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 1176, 1178, 1179, 1183, 1402, 1413, 1414. L.A.M. 122, 124, 302, 305, 305A. U.C. A-8333. U.C.L.A. 301, 305, 2420.

Original description. — Testa irregulariter ovata, inaequivalvi, albo-viridula, irregulariter plicata; valvaii superiore convexa, inferiore plana, suprene late perforata, foramine integro, marginibus acutis plicatis, valvis intus submargaritaceis, superiore maculamagna satirate viridi ornata. (Deshayes, 1839).

Remarks. — Numerous specimens, all single valves, in the collections from the San Diego formation are referable to this species. The largest specimen, a well preserved left (upper) valve, from Loc. 305 (LAM) is 77 mm high, from dorsal to ventral margin, and 94 mm wide; the smallest one is about 5 mm high. A large Recent specimen 102 mm high and 105 mm wide was reported from Morrow Bay, California (see Min. Conch. Club South. Calif., No. 190, p. 21, 1959). The fossil specimens vary in thickness. Some are rather coarsely sculptured with radial ribs, others bear fine sculpture as shown in Reeve's Illustrations of *"Placunanomia" cepio* Gray and *P. alope* Gray.

Fitch (571) stated that specimens of *Pododesmus* occurring on abalone shells in southern California are referable to the species described by Gray as *Placunanomia cepio* (572), a species generally placed in synonymy of *Pododesmus macrochisma.* Gray described *P. cepio* as follows: "Scars 2, far apart; upper very large, ovate, longitudinal, central; lower smaller, oblong, oblique, rather behind the upper," "Plug large, flat, broad. Notch large wide." Reeve illustrated a specimen under this name and stated: "Shell orbicular, radiately minutely striated, everywhere wrinkle-indented; transparent white; orifice rather large."

Placunanomia alope Gray (573), also described from California, has well defined radial sculpture as stated by Reeve, "In this species the ribs have an irregular character, disposed in waved radiating wrinkles."

The separation of *P. cepio* and *P. alope* from forms of *P. macrochisma* is based chiefly upon the thinner shell and finer sculpture. However, valves similar to *P. alope* from San Miguel Island, California, in the collections of the California Academy of Sciences, are accompanied by large, thick, rather coarsely sculptured valves. The thickness of the shell and the development of coarse or fine radial sculpture (occasionally obsolete) varies greatly depending upon the situs. Frizzell (574) mentioned a specimen which grew in an empty tube of a *Teredo.*

F. S. MacNeil mentioned (pers. comm.) that specimens referred to *Pododesmus macrochisma* from California generally have a larger byssal foramen than those from Alaska. We have examined this feature in a series of shells from Bering Sea to Lower California, Mexico. We have observed two rather thick Recent shells from Kodiak Island, Alaska, in which the foramens are comparatively small. However, somewhat thinner shells with larger foramens also are present in the collection from the same locality. Illustrations representing this species by Russian (575) and by Japanese authors (576) reveal rather large foramens. Size of the foramen does not appear to be consistently different in northern and southern forms.

It is true that some specimens from west American waters are similar to *P. cepio* and others to *P. alope* but the variation in a large series is so great that there appear to be no criteria to rely upon for separating the shells into two or three species unless certain forms are arbitrarily selected to represent various species. An examination of a large series of specimens of *P. macrochisma* in the Smithsonian Institution, and the type specimen of *P. alope*, led Carpenter (577) to conclude that it "proves that these forms are among the many varieties of *P. macrochisma*" (578). More recently Burch (579), after studying a large series of specimens of *Pododesmus* from Puget Sound and from Monterey, California, stated that he could find no basis for the recognition of more than one species.

We have observed large coarsely ribbed specimens referable to *P. macrochisma* which occur in beds of late Pliocene age in Ventura Co., California.

A variety (580) of *P. macrochisma* was described by Kanehara from Hokkaido, Japan, from beds now believed to be of Pliocene age.

Pododesmus newcombei Clark and Arnold (581) was based upon a fossil from Vancouver Island, British Columbia, in beds referred to late Oligocene age. The type measures approximately, length 35 mm, height, 29 mm. It was described as differing from *P. macrochisma* in the smaller size and fewer, coarser, radial ribs separated by wider interspaces.

Pododesmus foliata Broderip (582), a Recent tropical west American species, is sculptured with fine ribbing and the color of the interior is brown.

SUBCLASS TELEODESMATA DALL
ORDER PACHYODONTIDA STEINMANN
SUPERFAMILY CHAMACEA BLAINVILLE (583)
FAMILY CHAMIDAE BLAINVILLE (584)

Shell substance three-fold, the inner layer porcellanous and tubular, the middle obscurely prismatic, the external cellulo-crystalline with reticulated tubules and an inconspicuous epidermis; valves unequal, irregular, one of them sessile; closed, usually rounded in form with conspicuous sculpture, often differing in the opposite valves; adductor scars subequal, elongate, pedal scars minute, distant; ligament and resilium external in a deep groove, parivicular, opisthodetic; area distinct, prosodetic; beaks more or less spiral, prosogyrous; pallial line simple; hinge-plate heavy, arcuate; hinge frequently with a minute or obsolete posterior lamina, chiefly in the fixed valve;

cardinals one or two in the free valve, two with an intermediate socket in the fixed valve; the anterior cardinal broad, usually deeply grooved or multifid, the posterior simple, long, and curved parallel with the dorsal border. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 3, pp. 541-542, 1895). Late Cretaceous to Recent.

Remarks. — The supraspecific units of this family have been reviewed by Nicol (585). Many of the Recent west American species of Chamidae were reviewed by Pilsbry and Lowe (586) and others. Yonge recently discussed the "Form, Habit and Evolution in the Chamidae (Bivalvia) with reference to conditions in the rudistids (Hippuritacea)" (Phil. Trans. Roy. Soc. London, Ser. B. Biol. Sci., No. B. 775, Vol. 252, pp. 49-105, figs. 1-31, February 16, 1967).

GENUS *CHAMA* LINNAEUS (587)

Chama Linnaeus, Syst. Nat., ed. 10, p. 691, 1758. Several species cited including *Chama lazarus* Linnaeus. — Odhner, Kon. Svenska Vetensk. Akad. Handl., Bd. 59, No. 3, p. 75, 1919.

Type species (designated by Schmidt, Versuch Conchyl. Samml., pp. 63, 177, 194, 1818). — "Typ. *Chama Lazarus.* No. 11. v. Born. tab. 5, fig. 12-14". [*Chama lazarus* Linnaeus, 1758, p. 691. "Habitat in Mediterraneo, Americano." Ref. to "Rumph. mus. t. 48, f. 3", "Argenv. Conch, t. 23, f. F. I.", "Brown, jam. t. 40, f. 9." Illustrated by Reeve, Conch. Icon., Vol. 4, *Chama*, sp. 4, pl. 2, figs. 4a-b, 1846. For a discussion of *Chama lazarus* see Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 138, 1952.]

Range. — Late Cretaceous to Recent. Recent, shore to about 160 meters (86 fathoms). One species cited from a depth of 1250 meters.

Description. — Shell thick, attached at umbo of left valve which is often cornucopia-shaped; very inequivalve, the upper one the smaller; beaks prosogyrous, turned to the right; ornamentation concentrically foliaceous and irregularly lamellate or spinose; hinge tooth of upper valve thick, curved, received between two teeth in the opposite valve; ligament external but more or less sunken in a groove; adductor impressions large; margin usually finely crenellated.

Remarks. — *Chama* is separated from *Pseudochama* Odhner, type *Chama cristatella* Lamarck, which is attached by the right valve and has the beaks twisted to the left. Yonge mentioned (1967, p. 56) that some species in the Chamidae may be attached by either the right valve or the left valve and that genera cannot be erected on this basis. However, he stated that "It is also convenient, regardless of species, to refer to '*Chama*' and '*Pseudochama*' thereby denoted individuals attached by these valves."

Douvillé (588) suggested that *Chama* may have been derived from *Corbis* Cuvier [*Fimbria* Megerle von Mühlfeld] by attaching one valve for support.

Only three species of *Chama* have been reported from the Tertiary of western United States, one in the Oligocene of western Washington, and one each in the early Miocene and in the middle Pliocene of California. Four species have been recorded from beds of late Pliocene age in the Gulf of California region. This genus is here recorded from the San Diego Formation for the first time.

The species of *Chama* live chiefly in warm marine waters. Ten species live in west American waters, only one of which ranges north to California.

Chama pellucida Broderip
Plate 43, Figure 12, 15

Chama pellucida Broderip, Proc. Zool. Soc. London for 1834, p. 149, issued April 3, 1835. — Broderip, Trans. Zool. Soc. London, Vol. 1, p. 302, pl. 38, fig. 3, 1835. Original locality cited. — Reeve, Conch. Icon., Vol. 4, *Chama*, species 32, pl. 6, fig. 32, 1847. Original locality cited. — Woodring and Stewart, in Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, p. 38, and list opposite p. 78, pl. 14, figs. 1-4, 10, 1941. *Pecten* zone, San Joaquin Formation, Kettleman Hills, California, late Pliocene. — Abbott, American Seashells (D. Van Nostrand Co., Inc.: New York), p. 393, pl. 37, fig. a, 1954. Oregon to Chile. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 225, pl. 33, figs. 2, 2a; pl. 34, fig. 5, 1961. Oregon to Chile, Recent.

Type specimen. — Syntypes Nos. 1950-11.1.63-65, British Museum (Natural History).

Type locality. — "Hab. ad Peruviam. (Iquiqui)." "Dredged up attached to stones, *Mytili*, and turbinated shells, at a depth varying from nine to eleven fathoms, from a bottom of coarse sand; and also found under stones at low water mark."

Range. — Late Miocene (Castaic Formation; Stanton, 1966); middle Pliocene to Recent. Recent, western Oregon (Lat. 44° N.) to Cedros Island, Lower California, Mexico. Santa Elena, Ecuador, to Tocopilla, and Juan Fernandez Island, Chile. Intertidal zone to 46 meters (25 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A, 318, 319.

Original description. — Chama testa albâ roseo seu rubro frucatâ vel strigatâ, lamellis frequentibus, frondibus elongatis pellucidis; intùs albâ, limbo crenulata. (Broderip.)

Remarks. — This species is represented in the San Diego Formation by numerous small specimens, the largest is a left valve 17 mm high. A fragment 25 mm long bears spines similar to those on *Chama frondosa.* A number of small, eroded specimens are probably referable to this species.

Chama frondosa is here reported from the San Diego Formation for the first time. It has been reported from California in beds of Pliocene age at Los Angeles, in the San Joaquin Formation in Kettleman Hills, (and what is probably this species) from the Santa Maria district. It has been reported in beds of late Pliocene age in the Gulf of California region but we have not seen specimens.

The reported distribution of this species from Oregon to Chile, at the present time is an unusual one. Specimens from California agree closely with illustrations of this species by Broderip and by Reeve. We have not seen specimens from south of Cedros Island, Mexico, in North American waters. The species was not included by Keen in her volume on tropical west American shells. Confirmation of the identity of the form from California and Oregon with specimens from Peru is desirable.

The hinge teeth of this species in an early stage of development, have been illustrated by Dall (589). Grieser (590) published a paper dealing with the animal of *Chama*

pellucida and a recent paper by Yonge (1967) contains a detailed discussion of various features of this species.

Chama chilensis Philippi (591), described from beds of Quaternary age in Chile, was said to differ from *C. pellucida* in possessing less projecting concentric lamellae, which lack frondose extensions, as well as in differences in details of the hinge.

ORDER HETERODONTIDA NEUMAYR
SUPERFAMILY CRASSATELLACEA MENKE (592)
FAMILY CRASSATELLIDAE MENKE

Shell porcellaneous, solid, subtriangular to oblong, with convex or compressed umbones, the anterior side shorter, higher and rounded, the posterior contracted, flattened, pointed, or subtruncate. Hinge strong with large cardinal teeth and laterals. Ligament internal, attached to a resilifer groove between the cardinal teeth. Surface smooth or with growth line sculpture, sometimes concentrically undulate especially over the umbones. Pallial line simple, the adductor scars usually impressed. Ventral margin smooth or crenate. [Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 179, 1961.] Cretaceous to Recent.

The members of this group live chiefly in warm temperate and tropical waters. This family is well represented in the Eocene of western North America, but only a few species have been reported from the later Tertiary and Quaternary in this region.

GENUS *CRASSINELLA* GUPPY

Crassinella Guppy, Geol. Mag., Dec. 2, Vol. 1, p. 442, October 1874. Sole species, *Crassinella martinicensis* d'Orbigny. — Keen, Proc. Malacol. Soc. London, Vol. 23, Pt. 1, p. 30, 1938. "Genotype (by monotypy): *Crassinella martinicensis* (D'Orbigny 1853) (= *Crassatella martinicensis* D'Orbigny, 1853." — Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 72, 1953. "Type by monotypy: *Crassinella martinicensis* d'Orbigny." — Korobkov, Metodicheskoe Rukovodstvo Po Tretichnym Molluskam Plantinchatozhabernye [Lamellibranchiata] (Leningrad), p. 137, 1954. Type, *Crassatella martinicensis* d'Orbigny.

Not *Crassinella* Bayle, Explic. Carte France, Vol. 4, Fasc. 1, Explic. t. 105, 1878.

Pseuderiphyla Fischer, Man. de Conchyl., p. 1022, June 15, 1887. Sole species, *Crassatella martinicensis* d'Orbigny.

Type species (by monotypy). — *Crassinella martinicensis* d'Orbigny in Sagra, Hist . . . . Cubana, Vol. 7 (Moll., Vol. 2), p. 288,[?1845], Atlas, pl. 27, figs. 21, 22, 23, 1842. — Maury, Bull. Amer. Paleo., Vol. 10, No. 42, p. 330 (178), pl. 42 (31), fig. 2, 1925. "Matura," Trinidad, "Upper Pliocene." — Jung, Bull. Amer. Paleo., Vol. 55, No. 247, p. 352, pl. 22, figs. 1, 2, 1969. Trinidad, early Pliocene.

Range. — Eocene (593) in Europe and Argentina, late Oligocene (594) in the Americas, to Recent. Recent in warm temperate and tropical waters, from 1 to 73 meters (40 fathoms), and reported to a depth of 712 meters (390 fathoms).

Description. — Shell small, solid, subtrigonal with the lateral sides straight and subequal, the umbones flattened with the small beaks pointing backwards or opisthogyrate. Anterior side rounded, the posterior more excavated, concave, its end obtuse or pointed. Ligament is largely internal, the pit for the resilium forming a deep socket in the hinge plate; it is bordered in each valve by two strong cardinal teeth on the anterior side. Left valve with a strong posterior lateral tooth bordered above by a long linear socket. External surface smooth or with strong, concentric lamellations. Pallial line simple, the ventral margins plain. (Olsson and Harbison, 1953.)

Remarks. — This genus with small, trigonal, flattish, concentrically sculptured valves, is here reported from beds of Pliocene age in California for the first time. However, it is known to occur in beds of that age in Costa Rica and Ecuador.

The earliest geologic record of occurrence of *Crassinella* in California is that of "*Crassinella* cf. *C. mexicana* Pilsbry and Lowe" from strata of approximately middle Miocene (595) age.

Six species have been reported from beds of Pleistocene age in southern California and Lower California. Four species have been reported living in tropical and subtropical west American waters. The number of valid forms will probably be reduced when the relationship of the various west American species is known.

Crassinella branneri Arnold
Plate 43, Figures 24, 25, 28, 29

Astarte (Crassinella) branneri Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 127, pl. 18, fig. 12, June 27, 1903.

Crassinella branneri Arnold, Woodring, Bramlette, and Kew, U. S. G. S., Prof. Paper 207, p. 82, pl. 36, figs. 1-6, 1946, "characteristic of the Palos Verdes sand."

Type specimen. — No. 162527, United States National Museum.

Type locality. — "from the upper San Pedro series at Los Cerritos," California. "Pleistocene."

Range. — Middle Pliocene to late Pleistocene. Occurrence in San Diego Fm. — L.A.M. 305.

Original description. — Shell small, subtrigonal, equivalve, inequilateral, convex, thick; umbo small, sharp; anterior dorsal margin straight to anterior extremity, where it meets the arcuate ventral margin in an angle; posterior dorsal margin evenly arcuate, sloping down to rounded, posterior extremity; surface sculptured with numerous angular, concentric undulations or ridges; lunule long, narrow, extending to anterior extremity, and circumscribed by a narrow, angular ridge; ligament external, not prominent; two prominent cardinal teeth in right valve; one in left; no laterals; pallial line entire, running from the middle of adductor scars; adductor scars subequal, small. Dimensions. — Long. 10 mm; alt. 8.9 mm; diam. 5 mm. (Arnold.)

Remarks. — Several valves of this *Crassinella* were collected by G. P. Kanakoff near the Mexican boundary. These agree well with the original description and appear to be the species identified with *Crassinella branneri* by Woodring, Bramlette, and Kew.

The original illustration depicts a left valve, apparently rather thick and with a rather wide apical angle. There is a discrepancy in the dimensions given in the text and those on the explanation to the plate. Dr. W. P.

Woodring kindly informed us (written comm.,October 16, 1968) that the type specimen is 9.7 mm long. This corresponds rather well with the dimension given as 10 mm by Arnold on page 127 (text). Dr. Woodring also informed us concerning the hinge and lateral armature both of which agree well with the present specimens.

The anterior margin of the left valve of this species is grooved toward the ventral margin and a posterior lateral socket is parallel to the posterior margin throughout its length and into which the margin of the right valve fits. Some authors refer to the inner lamina (more strongly developed ventrally) as a posterior lateral. A similar anterior socket is present on the right valve.

There is considerable variation in the valves in the present collection. The larger ones are less concave posteriorly and are less strongly sculptured. The apical angle varies from about 78° to 82°.

Crassinella branneri bears a close resemblance to *C. pacifica* C. B. Adams (596), differing chiefly in the narrower posterior ventral end of the shell. *Crassinella mexicana* Pilsbry and Lowe (597) is nearly equilateral and the posterior dorsal margin is but slightly concave in outline.

Crassinella quintinensis Manger (598), described from beds of Pleistocene age at San Quintín, Lower California, appears to be referable to *C. branneri.* Specimens from the type locality were identified as *C. branneri* by E. K. Jordan and they reveal no noticeable differences in shell characters from Arnold's species.

Woodring, Bramlette, and Kew, mention that a "small race" of *C. branneri* lives in Scammon's Lagoon, Lower California. We have observed specimens of *C. mexicana* from that locality and further south at San Hipolito Point, some of which in profile approach *C. pacifica.* They may be but a subspecies of *C. pacifica* to which nomenclatorial status such forms were referred by Hertlein and Strong (599) and by Hoffstetter (600).

SUPERFAMILY CARDITACEA FLEMING (601)
FAMILY CARDITIDAE FLEMING

Shell suborbicular to subquadrangular, often cordate, usually heavy, with large, prominent umbones, anteriorly directed and varying in position from submedian to nearly terminal, the anterior side commonly the shorter. Sculpture consists typically of strong, radial ribs, usually noded, the surface covered by a brown, hairy periostracum. Ligament external. Hinge plate curved, usually with two cardinal teeth in each valve, the posterior one elongate and with the lateral teeth absent or more or less degenerated. Pallial line simple, the ventral margin more or less fluted or crenated by the ends of the radial ribs. Byssus usually present. [Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 184, 1961.] Triassic to Recent.

This family is represented by numerous species in the Paleogene of western North America, but the number was reduced in the Neogene. Four genera are present in the San Diego Formation. At the present time, carditids with large, thick shells live in tropical and subtropical waters, but small forms, which also occur in warm waters, are abundant in temperate and even Arctic waters. Frequently viviparous.

Freneix (602) discussed the development of the ligament and the hinge characters of the Carditidae and Yonge (603) discussed the functional morphology and evolution within the Carditacea.

Key to Genera of Carditidae

A. Shell high and subtrigonal
  a. Hinge of left valve with an anterior lateral tooth. . . . . *Miodontiscus*
  aa. Hinge of left valve lacking an anterior lateral tooth . . . . *Cyclocardia*

B. Shell oblong or elongately trapezoidal
  a. Ventral margin of valves folded inward . *Milneria*
  aa. Ventral margin of valves not folded inward . . . . . *Glans*

GENUS *CYCLOCARDIA* CONRAD

Cyclocardia Conrad, Amer. Jour. Conch., Vol. 3, No. 2, p. 191, September 5, 1868. *Cardita borealis* Conrad and *Cardita ventricosa* Gould cited. — Lamy, Jour. de Conchyl., Vol. 66, No. 4, p. 293, 1922. "Type *V. borealis* Conrad." — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Paper No. 3, p. 150, 1930.

Arcturus Sowerby, Zool. Beechey's Voy., Moll., p. 152, 1839. *Arcturus rudis* Humphrey MS in synon. of *Cardita borealis* Conrad.

Not *Arcturus* Berthold in Latreille, 1827. Crustacea. Not *Arcturus* Curtis. Lepidoptera.

Scalaricardita Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 27, p. 22, September, 1899. Species cited, "*Miodon* (an *Scalaricardita) scalaris* (Sow.)", and in the synonymy, *Cardita producta* Michelotti, 1847.

Type species (designated by Stoliczka, Mem. Geol. Surv. India, Palaeont. Indica, Ser. 6, Cret. Fauna South. India, Vol. 3, Pelecypoda, pp. XX, 281, 1871). — "Type, *C. borealis*, Con." [Amer. Mar. Conch., p. 39, pl. 8, fig. 1, 1831. Illustrated by Stearns, Proc. U. S. Nat. Mus., Vol. 13, No. 813, p. 215, pl. 16, fig. 8, 1890. (Fig. of type). — Abbott, Amer. Seashells, p. 379, pl. 28, fig. t, 1954.]

Range. — Middle Oligocene (604) to Recent. Recent from 18 to 2195 meters (10 to 1200 fathoms).

Original description. — Rounded, equivalve, radiately costate, covered with a rough epidermis; hinge with two robust teeth in the left valve, directed obliquely backward, the posterior one elongated and slightly curved; anterior tooth of the right valve rudimentary; pallial impression entire. (Conrad, 1868.)

Remarks. — *Cyclocardia* Conrad is here retained in a generic category because of the unsettled state of nomenclature concerning the type species of *Cardita* Bruguière (605) and *Venericardia* Lamarck. The species assigned to *Cyclocardia* are usually rounded trigonal and covered with a rough periostracum. The cardinal tooth on the right valve of some species is bifid or grooved, but on others this feature is only faintly developed.

Cyclocardia has been cited from widely separated regions. It occurs in the Arctic, temperate, sub Antarctic, and Antarctic (606) regions. Finlay and Marwick (607) stated that in New Zealand, *Cyclocardia* first appeared in the Duntroonian, late Oligocene, and last appeared in the

Awamoan, middle Miocene. Sieber (608) cited it from late Tertiary beds in the Vienna basin. Hirayama (609) listed 32 species, Recent and fossil, of small "*Venericardia*" from Japan and stated that probably half of these are referable to *Cyclocardia*. It has been reported from strata of middle Oligocene age in Germany, and in western North America *Cyclocardia* first appeared in late Oligocene or early Miocene time. Recent species in this region occur from the Arctic to slightly south of San Diego, California. One species living in tropical west American waters was recently assigned to *Cyclocardia* by Keen (Sea Shells of Tropical West America, p. 109, 1971). Chavan (610) briefly discussed the occurrence of *Cyclocardia* and pointed out that it is essentially an American group.

Woods (611) long ago called attention to the similarity existing between the late Tertiary species of Europe, *Cardita scalaris* Sowerby, the type species of *Scalaricardita*, and *C. ventricosa* Gould. The similarity is so great that it leads to the placement of *Scalaricardita* Sacco in the synonymy of *Cyclocardia* as was recently done by Sieber.

Key to Species of *Cyclocardia*

A. Radial ribs 14 to 17; dorsal-ventral elongation . . . . . *occidentalis*

B. Radial ribs 18 to 20; anterior-posterior elongation . . . . . *ventricosa*

Cyclocardia occidentalis Conrad
Plate 43, Figures 4-6, 9-11

C[ardita]. occidentalis Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 7, p. 267, February, 1855. — Conrad, U. S. Pac. Railroad Expl., Vol. 6, Pt. 2, No. 2, p. 73, pl. 5, fig. 24, 1857. "Locality. — Santa Barbara, California."

Cardita monilicosta Gabb, Proc. Acad. Nat. Sci. Philadelphia, Vol. 13, p. 371, November, 1861. "From the Tertiary (probably Miocene) of Santa Barbara, Cal."

Venericardia borealis Conrad, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "well at San Diego." "Pliocene." — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 269, 1888. "Pl. — San Fernando, Los Angeles County; Santa Barbara to San Diego." — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, 1889. Dall's record (1874) cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, pt. 1, p. 48, 1944. Dall's record (1874) cited.

Not *Venericardia borealis* Conrad, 1831.

Venericardia monilicosta Gabb, Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 28, 1878. P. 28 "well-digging in stratum B^2, "San Diego, California." — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 86, 1889. Dall's record (1878) cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S. Water Supply Paper 446, p. 60, 1919. Dall's record (1878) cited. — Arnold, U. S. G. S., Bull. 321, p. 32, pl. 14, fig. 2, 1907. "Fernando formation, Bath-house Beach, Santa Barbara." "Fernando (Pliocene)." [Pleistocene.]

Venericardia ventricosa Gould, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 129, 1903. "Pliocene. — San Fernando; Santa Barbara to San Diego (Cooper): San Pedro; Santa Barbara (Arnold)." Also other records.

Not *Venericardia ventricosa* Gould, Proc. Boston Soc. Nat. Hist., Vol. 3, p. 276, July 1850. "Hab. Puget Sound."

Type specimen. — "not known to be extant" (Woodring, 1946).

Type locality. — "Occurs with the preceding" [that is] "Locality. — California." In 1857 cited from "Santa Barbara, California."

Range. — Middle and late Pliocene and Pleistocene of southern California.

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 12096. L.A.M. 305A, 318, 323. S.D. 75, 124, 2359.

Original description (of *Cardita occidentalis*). — Subtriangular, equilateral; ventricose; ribs 15, rounded, wider than the interstices, and regularly granulated by transverse lines. (Conrad, 1855.)

"Allied to *C.* _____, of the San Pedro recent formation, but proportionally more elevated and having more prominent granules." (Conrad, 1855.)

Original description of *Cardita monilicosta.* — Shell nearly circular; beaks small, submedian, cardinal border straight or faintly arcuate. Surface marked by from fourteen to seventeen large rounded ribs, strongly moniliform; interspaces narrow, acute. Posterior muscular impressions largest. Pallial line broad and distinct but not impressed. Internal margin coarsely crenulate, one large square tooth, corresponding with each interspace between the ribs; extreme edge undulated. Hinge robust. Length, 0.19 in.; width, 0.2 in.; depth of single valve, 0.05 in. (Gabb, 1861.)

Remarks. — Three specimens with both valves and four single valves of a *Cyclocardia* collected by Henry Hemphill from the San Diego well are in the collections of the California Academy of Sciences. The largest specimen is 12.6 mm long, 11.4 mm high, convexity (both valves together), 9 mm. These have about 15 nodulose ribs. The original label cites "*Venericardia ventricosa* Gld. = *monilicosta* Gabb." A left valve in the collection of the University of California at Los Angeles from North Snyder School, Cabrillo Freeway, in San Diego, is 13.7 mm long, 14 mm high, convexity, 5.1 mm. Four very small single valves from Loc. 323 (LAM) are referable to this species.

The correct identification of these specimens is fraught with certain difficulties. For this reason the original descriptions of both *Cardita occidentalis* and *C. monilicosta* Gabb are included in the present work.

The specific name *occidentalis* appears to be the earliest name applicable to the present specimens. The description is applicable and the original illustration, although not satisfactory, has in general the outline and the sculpture similar to that of the present specimens.

The later name *Cardita monilicosta* Gabb, also based on specimens from Santa Barbara, has been relegated to the synonymy of *C. occidentalis* by various authors. Judging from the description, this appears to be the logical course.

The present specimens agree almost exactly with the illustration given by Arnold of a specimen from beds of Pleistocene age at Santa Barbara, California, under the name *Venericardia monilicosta* Gabb. This is certainly

referable to the same species illustrated by Woodring, Bramlette, and Kew (612) under the name of *Cardita* aff. *C. occidentalis* Conrad from Pleistocene beds at San Pedro, California, shown on their plate 33, figure 4. The specimens illustrated under the same name on their plate 31, figures 9 and 10, are more elongately rounded in outline and with flatter, less nodose ribs, and bear a resemblance to the *C. ventricosa* series discussed by Smith and Gordon (613). Quayle (614) believed that *C. occidentalis* and *C. monilicosta* are separable, basing his conclusions upon measurements of specimens.

Willett (615) mentioned the probable identity of *C. occidentalis* with *C. monilicosta* and he also mentioned a resemblance to *C. stearnsii* Dall (616), which, however, is a distinct species living in Puget Sound. Woodring, Bramlette, and Kew, (1946, p. 85) pointed out that the nodulose specimen illustrated on their plate 33, figure 4 bears a resemblance to *C. californica* Dall (617). The latter species does bear a general resemblance to *C. occidentalis* but is more narrowly trigonal in outline and the ribs, about 14-16 in number, are very coarsely nodulose and the shell is larger and quite thick.

A study of the small specimen, upon which the senior author based the record (618) of *Venericardia californica* Dall from the San Diego formation, reveals that it can be referred to *C. occidentalis.*

Fossils described under the name of *Cardita monilicosta* Gabb var. *ochotica* Slodkewitsch (619) from the Kavran Series of Pliocene age in western Kamtschatka, resemble Gabb's species in general characters but are said to possess 21-23 radial ribs and the outline of the shell was said to be more rounded. Perhaps this is the form cited by Tikonovich (620) from beds of Pliocene age on the Schmidt Peninsula, Sakhalin Island. According to Slodkewitsch, typical *C. monilicosta* Gabb was not found by him among the collections from Sakhalin or Kamtschatka.

Cyclocardia ventricosa Gould
Plate 43, Figures 3, 8

Cardita ventricosa Gould, Proc. Boston Soc. Nat. Hist., Vol. 3, p. 276, July, 1850. — Gould, U. S. Explor. Exped., Vol. 12, p. 417, 1852, Atlas, p. 14, pl. 36, figs. 532, 532a, 1856. — Gould, Otia Conch., pp. 83, 246, 1862. "Hab. Puget Sound." — A. G. Smith and Gordon, Proc. Calif. Acad. Scil, Ser. 4, Vol. 26, No. 8, pp. 214, 215, figs. 4A, B, 1948. "Puget Sound." Recent.

Venericardia ventricosa Gould, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 174, 182, 1912. "San Diego-Purisima." — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 36, pl. 3, fig. 8, 1924. Puget Sound. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 114, 1924. "Range. Belkoffski Bay, Alaska, to the Coronado Islands and Cortez Bank."

Type specimen. — Syntypes No. 3373, United States National Museum; also Syntype No. 216813, Museum of Comparative Zoölogy, Harvard University (Johnson, U. S. Nat. Mus., Bull. 239, p. 165, 1964).

Type locality. — "Hab. Puget Sound."

Range. — Middle Pliocene to Recent. Recent from Belkoffski Bay, Alaska, to the Coronado Islands and Cortez Bank, Mexico, in 37 to 272 meters (20 to 149 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A.

Original description. — Testa solida, ventricosa, ovato-trigona vix obliqua, radiatim 18-20 costata, costis concentricè subnodosis, interstitiis angustis, epidermide fuliginoso, villoso induta; umbonibus submedianis, obtusis; intus alba; margine profundè crenulato; dente cardinali valvae dextrae, elevato, crasso, triangulari. Lat. 3/4; alt. 5/8; lat. 1/2 poll. (Gould).

Compared with *C. borealis*, Conr., it is thicker, less transverse, more tumid at the beaks, which are less recurved; the ribs are barred; the cardinal tooth is short, triangular (not long falcate) and detached from the margin; the crenulations of the margin deeper. (Gould.)

Remarks. — The largest of four single valves from Loc. 305 (LAM) is a left valve 16.2 mm long and 15 mm high. There are 18 radial ribs of which the posterior 5 or 6 are smaller than the others. This valve as well as the smaller ones, compares favorably with Recent specimens of *Cyclocardia ventricosa* from Puget Sound and California.

So far as we can ascertain, most of the earlier records of this species from the San Diego Formation were based upon Dall's record (1874) which is referable to *Cyclocardia occidentalis* Conrad. The shell of *C. ventricosa* is more elongately (anterior-posterior) rounded and is sculptured with 18 to 20 rather than 14 to 17 radial ribs.

A Recent form from Monterey, California, more elongate (anterior-posterior) than usual for this species was named *C. ventricosa montereyensis* (621) by A. G. Smith and Gordon. Inspection of a large series of specimens of this subspecies reveals that there are forms which imperceptibly grade into typical *C. ventricosa.*

A small southern form, more rounded in outline and more inflated, with more sharply defined ribs, was described as *C. ventricosa redondoensis* by J. Q. Burch (622).

Wood (623) mentioned a close resemblance of *Cardita scalaris* in the Coralline and Red Crag of England to *C. ventricosa.* However, his description of the Crag fossil calls for 20 to 22 radial ribs and his figure suggests a more trigonal shell.

Cyclocardia inflata Hayasaka and Uozumi (624), described from beds of late Oligocene or early Miocene age in Japan, was said to be more rounded in outline and the umbo lower than that of *C. ventricosa.*

Barnard and Ziesenhenne (625) mentioned the occurrence of 132 specimens of *Cyclocardia ventricosa* per square meter on an "*Amphiodia-Cardita*" bottom off southern California.

Viviparity in this and other species of the Carditidae was discussed by Jones (626). A detailed discussion of *C. ventricosa* was published recently by Yonge (Proc. Malacol. Soc. London, Vol. 38, Pt. 6, pp. 494-505, figs. 1-9, 19, 24a, December, 1969).

GENUS *GLANS* MERGERLE VON MÜHLFELD

Glans Megerle von Mühlfeld, Mag. Gesell. Naturfor. Freunde zu Berlin, year 5, p. 68, 1811. Sole species, *Glans trapezia* Linnaeus. — Lamy, Jour. de. Conchyl., Vol. 66, No. 3, p. 222, 1922. "Type: *C. trapezia* Linné." — Palmer, Geol. Soc. Amer., Mem. 76, p. 82, 1958. "Type species by monotypy *Glans trapezia* (Linnaeus)."

Type species (by monotypy). — *Glans trapezia* Linnaeus [= *Chama trapezia* Linnaeus, Syst. Nat., ed. 12, p. 1138, 1767. "Habitat in Oceano Norvegico." Illustrated by Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 6, p. 231, pl. 38, figs. 21-25, 1892. — Dollfus and Dautzenberg, Mém. Soc. Géol. France, Paléo., Vol. 16, Fasc. 2, Mém. No. 27, p. 292, pl. 12 (Mém. pl. 20), figs. 16-23, 1909 [as *Cardita (Glans) trapezia*]. Aquitanian, Miocene to Recent. Does not occur in Norway (p. 294). — Cossmann and Peyrot, Act. Soc. Linn. Bordeaux, Vol. 66 (Conch. Néog. de l'Aquitaine, Vol. 2, Livr. 1), p. 31, figure of hinge, 1912.]

Range. — Paleocene to Recent. Recent from the intertidal zone to 91 meters (50 fathoms).

Description. — Shell bearing a general resemblance to carditids such as *Carditamera* but small, subquadrate in outline; hinge with well developed anterior and posterior laterals.

Remarks. — This genus is represented by one species, occurring both as a fossil and Recent, in western United States. *Cardita naviformis* Reeve (627), which lives in waters off the coast of Chile, also has been assigned to this genus.

Paraglans Chavan (628) was proposed as a subgenus to include a number of Eocene species formerly placed in the genus *Glans*.

Glans subquadrata Carpenter
Plate 43, Figures 16, 18, 19, 22, 30

Lazaria subquadrata Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 536, 627, 642, issued August; 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 22, 113, 128, 1872. — Carpenter, Ann. Mag. Nat. Hist., Ser. 3, Vol. 15, p. 178, 1865. Reprint, 1872, p. 280. "Hab. Sta. Barbara (Jewett); Monterey, and along the coast to S. Pedro (State Coll. no. 403) (Cooper)."

Cardita (Carditamera) subquadrata Carpenter, Dall, Proc. Acad. Nat. Sci. Philadelphia, Vol. 54, Pt. 4, p. 707, 1902. Queen Charlotte Islands, Canada, to Todos Santos Bay, Lower California.

Not *Cardita subquadrata* Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 3, p. 298, 1847. "Eocene rocks in St. Matthew's Parish, Orangeburg District, S. D."

Not *Cardita subquadrata* Gabb, Jour. Acad. Nat. Sci. Philadelphia, Ser. 2, Vol. 4, p. 303, pl. 48, figs. 22a, 22b [indicated as 21a, 21b on plate], March, 1860. New Jersey, Cretaceous.

C[ardita]. (Carditamera) carpenteri Lamy, Jour. de Conchyl., Vol. 66, No. 3, p. 264, June 20, 1922. New name for *Lazaria subquadrata* Carpenter.

Glans minuscula Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 277, pl. 13, figs. 10a, 10b, November 3, 1931. Pleistocene and Recent. New name for *Lazaria subquadrata* Carpenter.

Glans subquadrata Carpenter, K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 82, pl. 7, figs. 1-4 (syntypes), 1958. Earlier records cited.

Type specimen. — Syntypes in United States National Museum, No. 15681 (Palmer, 1958).

Type locality. — "Recent. Monterey, California (type)" (Palmer, 1958). Several localities originally indicated by Carpenter, including "Neighbourhood of Monterey." "Neighbourhood of Sta. Barbara." "Vancouver Island, Straits of S. Juan de Fuca, and adjoining shore of Washington Territory . . ."

Range. — Middle Pliocene to Recent. Recent from Queen Charlotte Islands, British Columbia, to Todos Santos Bay, Lower California, from intertidal zone to 91 meters (50 fathoms). Usually in shallow marine waters, attached to the underside of stones or other objects.

Occurrence in San Diego Fm. — L.A.M. 305, 305A.

Original description. — "Hinge of *Lazaria*: outside like *Cardita variegata*, jun." (Carpenter, 1864).

L. testa extus *Carditae variegatae* jun. simili; pallida, castaneo tincta; subquadrata, antice truncata, subregulariter ventricosa, dorsaliter tumida; costis radiantibus circ. xiv-xvi., tumidis, nodosis, diagonalibus majoribus; interstitiis plus minusve insculptis: intus, valva dextra dente cardinali triangulari, inter duas fossas sito, haud elongato; dent. lat. a cardine separatis, ant. extante, post. obsoleto, calloso: v. sinistrali dent. card. ii. angustis, subaequalibus, radiantibus; lat. ant. et post. extantibus: cicatr. adduct. subrotundatis. Long. .37, lat. .25, alt. .34. (Carpenter, 1865.)

The outside of this remarkable little species is typically carditoid; the hinge is intermediate between *Lazaria* and *Cypricardia*. (Carpenter, 1865.)

Remarks. — A number of single valves of this species, the largest one 5.8 mm long, was collected by G. P. Kanakoff near the Mexican boundary. The shell characters of these are identical with those of Recent specimens from adjacent waters.

Lamy, and later Grant and Gale, placed *Lazaria subquadrata* Carpenter in the genus *Cardita*. They therefore proposed a new specific name for Carpenter's species because of the prior *Cardita subquadrata* Conrad, 1847, and of Gabb, 1860. Woodring, Bramlette, and Kew (629), and later Palmer, pointed out that if Carpenter's species is not referable to the genus *Cardita* or if the species described by Conrad and by Gabb are not assigned to the genus *Glans* then a new name is not necessary for *Lazaria subquadrata*. According to Woodring, Bramlette, and Kew, "it is improbable that either Conrad's or Gabb's *Cardita subquadrata* is to be assigned to *Glans*."

The only other reported occurrence of *Glans subquadrata* in beds of undoubted Pliocene age is in the Cebada Member of the Careaga Sandstone in the Santa Maria district.

Orcutt (630) reported *Cardita subquadrata* from strata of "Tertiary" age at Pacific Beach but his query "?Pleist." leads us to omit assignment of his record to the San Diego Formation.

A detailed discussion of this species was published recently by Yonge (Proc. Malacol. Soc. London, Vol. 38, Pt. 6, pp. 505-509, figs. 10-13, 20-22, 1969).

GENUS *MIODONTISCUS* DALL

Miodon Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 611, 627, 642, 682, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 97, 113, 128, 168, 1872. Species originally cited: "*Miodon prolongatus*"; "*Astarte orbicularis*, J. Sby."; "*Cardita corbis*." — Dall, Proc. Acad. Nat. Sci. Philadelphia, Vol. 54, Pt. 4, p. 700, January 20, 1903. "Type *M. prolongatus* Carpenter."

Not *Miodon* Duméril, 1859; not *Miodon* Sandberger, 1870.
Miodontiscus Dall, Nautilus, Vol. 16, No. 12, p. 143, April, 1903. A new name for *Miodon* Carpenter, 1864, not *Miodon* Duméril, 1859, nor *Miodon* Sandberger, 1870. — Lamy, Jour. De Conchyl., Vol. 66, No. 4, p. 293, 1922. "type: *V. prolongata* Cpr." — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 83, 1958. "Type species by original designation *M. prolongatus* Carpenter."

Type species (by subsequent designation, Dall, 1903): "Type *M. prolongatus* Carpenter." [The use of "n. subg. n. s." by Carpenter (1864, p. 627), is considered by K. V. W. Palmer, 1958, to be an original designation of *M. prolongatus* as type species.]

Range. — Miocene to Recent. Recent in from 9 to 128 meters (5 to 70 fathoms).

Description (of *Miodon* Carpenter). — Shell ovately subtrigonal, small, solid, ventrally much produced, with the umbones situated anteriorly, radiately ribbed, the ribs being partially intersected by concentric sulcations; hinge in the right valve with one posterior cardinal and one anterior lateral tooth, left valve with one triangular anterior and one elongated posterior cardinal, and a very small anterior lateral tooth. Closely allied to *Pleuromeris.* (Tryon, G. W., Jr., Structural and Systematic Conchology, Vol. 3, p. 233, 1884.)

Remarks. — Dall, 1903, mentioned that this genus is similar to *Pteromeris* Conrad (631) "but not compressed, and with the posterior (instead of the anterior) right cardinal absent and a posterior right and anterior left lateral developed feebly."

Iredale (632) believed *Miodontiscus* to be a synonym of *Coripia* De Gregorio (633) but Dall and most later authors consider *Coripia* to be a synonym of *Pteromeris.*

Miodontiscus has been reported from beds of Miocene age in Japan but up to the present time it has not been recorded earlier than middle Pliocene in western North America.

Miodontiscus prolongatus Carpenter
Plate 56, Figures 1-5

Miodon prolongatus Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 611, 627, 642, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 97, 113, 128, 1872. P. 97 "(Neeah Bay, Swan)", p. 128, indicated as from "Vancouver Island, Straits of S. Juan de Fuca, and adjoining shores of Washington Territory . . ." — Carpenter, Ann. Mag. Nat. Hist., Ser. 3, Vol. 14, p. 424, December, 1864. Reprint in Smithsonian Misc. Coll., No. 272, p. 236, 1872. "from Vancouver District." — Stearns, Proc. U. S. Nat. Mus., Vol. 13, No. 813, p. 217, pl. 16, figs. 7, 9, 1890. "from Neeah Bay, and Mr. Dall obtained several examples in the Alaskan region at Middleton Island." [Figured specimen from Middleton Island.]

Venericardia (Miodontiscus) prolongata Carpenter, I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 36, pl. 16, figs. 5, 6, March, 1924. Middleton Island, Alaska, to San Diego, California. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 115, pl. 2, figs. 5, 6, 1924 (as *Venericardia prolongata).* [Same illustrations and range as in preceding reference.]

Cardita (Miodontiscus) prolongata Carpenter, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 276, 1931. Pleistocene to Recent.

Miodontiscus prolongatus Carpenter, Chavan, Compt. Rend. Sci. Soc. Géol. France, No. 10, p. 122, 1937. — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 83, pl. 8, figs. 1-7, 1958. Earlier records cited. Syntype illustrated.

Type specimens. — "Syntypes. — U. S. National Museum, no. 15472; Redpath Museum, no. 2377" (K. V. W. Palmer, 1958).

Type locality. — "Neah Bay, Washington (type)" (Palmer).

Range. — Middle Pliocene to Recent. Recent from Middleton Island, Alaska, to San Diego, California, in 9 to 55 meters (5 to 30 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 309, 323.

Original description. — "Outside Lucinoid; hinge and scars nearer to *Venericardia.* Congeneric with *Astarte orbicularis,* J. Sby. Min. Conch. pl. 444, f. 2, 3 (non ejusdem, pl. 520, f. 2). G. Oolite; and with the Crag *Cardita corbis."* (Carpenter, August, 1864.)

Supplementary description: M. testa parva, solida, tumida, compacta, albida; ventraliter antice valde prolongata, excurvata; lunula longa, rectiore, haud impressa; umbonibus antice inflectis, obtusis, valde prominentibus; margine dorsali postico parum excurvato; costis radiantibus, x.-xii. latis, obtusis, marginem attingentibus, parum expressis, dorsaliter obsoletis, a liris incrementi concentricis, plus minusve distantibus, expressis, hic et illic interruptis: intus, margine a costis plus minusve obsoletim crenulato; cardine dentibus v. dextr., uno postico, inter duas fossas elongato, et. lat. ant. lunulari; v. sinistr., dent. ant. triangulari, post. valde elongato, lat. ant. minimo, obsoleto; cicatr. add. subrotundatis, ventraliter sitis. Long. .23, lat. .24, alt. .16. (Carpenter, December, 1864, p. 424.)

Remarks. — Typical specimens of *Miodontiscus prolongatus* are about 5 mm in length and in height. They are trigonally subcircular in outline with rather prominent, erect beaks which are slightly curved anteriorly. The external sculpture consists of broad, low, radiating ribs and widely spaced concentric, incised lines.

About 20 single valves in the present collection are referable to *Miodontiscus prolongatus.* The largest one, a left valve (ventral margin imperfect), is 7.9 mm high and 6.8 mm wide. Some of the valves are considerably eroded but the observable shell characters agree well with Recent specimens of Carpenter's species.

Woodring (634) reported comparable specimens from the Cebada and Graciosa members of the Careaga Formation in Santa Barbara Co. He considered *Venericardia yatesi* Arnold (635) to be a synonym of *M. prolongatus.*

Carpenter's description of *M. prolongatus* calls for 10 to 12 radiating ribs and the illustrations by Palmer show about this number. Arnold's description of *Venericardia yatesi* calls for 8 to 9 radial ribs. We have not studied a series of Arnold's species and can offer no opinion as to its identity with *M. prolongatus,* but it seems likely that variation in the species may be sufficient to justify placing it in the synonymy of Carpenter's species.

Slodkewitsch (636) reported *M. prolongatus* from beds of late Tertiary age in western Kamtschatka as did Pleshakov (637). However, according to Slodkewitsch,

his specimens are sculptured with 18 to 21 radial ribs. Those specimens, no doubt, are referable to some other species.

Cardita (Miodontiscus) nakamurai annakensis Oinomikado (638) described from the late Tertiary of Japan was compared by its author with *M. prolongatus.*

GENUS *MILNERIA* DALL

Ceropsis Dall, Amer. Jour. Conch., Vol. 7, Pt. 2, p. 152, November 2, 1871.

Not *Ceropsis* Gay and Solier, 1839. Coleoptera.

Milneria Dall, Amer. Nat., Vol. 15, No. 9, p. 718, September, 1881. A new name for *Ceropsis* Dall, 1871, not *Ceropsis* Gay and Solier, 1839. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1411, October, 1903. "Type *Ceropsis minima* Dall, 1871." — Lamy, Jour. de Conchyl.,Vol. 81, No. 4, p. 299, 1937.

Type species (by original designation). — "Type *Ceropsis minima*, n. s."

Range. — Middle Pliocene to Recent. Recent from Monterey, California, to Punta Abreojos, Lower California, and Guadalupe Island, from the intertidal zone to 27 meters (15 fathoms).

Description. — Shell with two left and three right cardinals, the posterior left lateral, posterior and anterior right cardinals minute and hardly recognizable except in very well-developed specimens, in which the formula is

L. 1.01010.
R. 0.10101.

The female has a dome-like indentation rising from the ventral margin of the valves, which is closed only by an extension of the mantle edge and therefore not included within the shut valves. The animal is minute, byssiferous, and a nestler on flat surfaces, like the backs of the shells of *Haliotis.* (Dall, 1903).

Remarks. — This genus is dioecious. The young are incubated in a fold in the mantle until they pass the prodissoconch stage.

This is the first record of the occurrence of *Milneria* in the San Deigo Formation. The genus was reported by Vedder (639) from strata of late Pliocene age in the Los Angeles basin. It also was reported by Woodring from beds of Pleistocene age in the Palos Verdes Hills, San Pedro, California.

Milneria minima Dall
Plate 43, Figures 1, 2, 14

Ceropsis minima Dall, Amer. Jour. Conch., Vol. 7, Pt. 2, p. 152, pl. 16, figs. 5, 6, November 2, 1871.

Milneria minima Dall, Lamy, Jour. de Conchyl., Vol. 66, No. 4, p. 353, fig. (p. 352), 1922. San Diego, California. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 117, pl. 54, figs. 29, 30, 31, 1924. "Monterey, California, to Rosario Bay, Lower California." — Lamy, Jour. de Conchyl., Vol. 81, No. 4, p. 299, fig. 9 (1, 2), 1937. — Franc, Traité de Zool., Tom. 5, Fasc. 2, p. 2095, fig. 1774, 1960. "de California."

Type specimen. — No. 63349, United States National Museum.

Type locality. — "Habitat, nestling or burrowing in *Haliotis rufescens*, at Monterey, also dead on beach, Dall; nestling under stones at low water, Canfield, Stearns, and Cooper."

Range. — Middle Pliocene to Recent. Recent from Monterey, California, to San Geronimo Island, near Rosario Bay, Lower California, Mexico, from the intertidal zone to a depth of 27 meters (15 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305.

Original description. — Shell minute, trapeziform, white, with a thin brownish epidermis. Umbones prominent, nearly terminal. Anterior margin rather strongly angulated; basal margin straight, or a little concave; lower posterior extremity angulated; upper posterior angle rounded off; posterior margin rather oblique. Hinge line smooth, rather broad. Ligament conspicuous, moderately long. A rounded carina passes from the umbo to the lower posterior angle, above which are from two to five radiating ribs. General sculpture of sharp elevated lines of growth, which become vaulted scales on the ribs. Margin lightly crenulated. Interior polished; muscular and pallial impressions indistinct. Long. 14, lat. .08, alt. .175 in. (Dall.)

Remarks. — Three valves of this species are present in the collection from Loc. 305 (LAM). One of these, a well preserved right valve, is 5 mm long.

This is the first record of *Milneria minima* in beds of Pliocene age but it was reported by Vedder (640) from a terrace of Pleistocene age on San Nicolas Island, California.

Woodring reported the occurrence of *Milneria kelseyi* Dall (641) from beds of Pleistocene age in the Palos Verdes Hills, San Pedro, as did Chace, 1966, and Vedder (1960) reported "*Milneria* cf. *M. kelseyi*" from strata of Pliocene age in the Los Angeles basin, California. That species in some cases has been confused with *M. minima.* The major radial ribs on *M. minima* are rather coarse and are about equal in size, whereas those on *M. kelseyi* are finer and less coarsely scaled. The umbonal and one or more of the other ribs, are higher than the rest. Furthermore the lunule of *M. kelseyi* is smaller and the escutcheon larger than that of *M. minima. Milneria kelseyi* attains a greater size than *M. minima*, up to 8 mm long, and is said to be the one more commonly found under rocks along the seashore.

SUPERFAMILY LEPTONACEA GRAY (642)

Remarks. — Most of the members of this superfamily possess small, thin shells, and often nestle in crevices, in holes in rocks, or in empty shells, Such habitat often results in distortion and variability in shape of the shells. Some forms live symbiotic with other invertebrates such as echinoderms, sponges, and crustacea. The exact relationships of the members of this superfamily are unknown.

Dall (643) published a synopsis of the Recent and Tertiary Leptonacea of North America and Laseron (644) recently presented a revision of the Leptonidae of New South Wales, Australia.

Some authors have included this group of mollusks under the Erycinacea and Erycinidae (645). However,

Swainson (646) in 1832-1833 used the family name Erycinidae in the phylum Insecta. Later Wood (647) included many of the genera of these small mollusks in the Fragillidae. Until the higher categories of molluscan nomenclature are more stabilized, it seems best to include this group under the well known superfamily name Leptonacea.

Chavan (648) recently discussed the hinge characters of the superfamily "Erycinacea." He placed the following six families under this category: Erycinidae, Kelliidae, Leptonidae, Montacutidae, Galeommatidae, Kelleyellidae.

A paper by Popham (649) contains the results of a study of the mantle cavities of some members of this superfamily, and a publication by Oldfield (650) deals with their reproduction and development. Boss (651) recently discussed the symbiotic habits of this group of small bivalves.

In the present paper we have assigned as members of the Leptonacea, the families Kelliidae and Montacutidae. Clark, the author of those families considered the well known genus *Lepton* Turton (652) to be quite distinct from the genera included in those groups.

FAMILY KELLIIDAE FORBES AND HANLEY (653)

Shell small, ovate or obicular, thin, convex, white or subtranslucent, the umbones and beaks submedian or anterior. Surface smooth and often glossy, occasionally punctate or partially radially ribbed; external ligament small, the internal resilium attached to a posteriorly directed oblique groove; hinge with one or two cardinal teeth and, usually one or two posterior lateral teeth in each valve, but lacking in some genera; pallial line simple; surface of exterior sometimes covered by the mantle. (Adapted in greater part from Olsson, Mollusks of the Tropical Eastern Pacific, Paleo. Res. Inst.: Ithaca, New York, p. 231, 1961.) Paleocene to Recent.

GENUS *ALIGENA* LEA

Aligena H. C. Lea, Proc. Amer. Philos. Soc., Vol. 3, p. 163 September, 1843. *Aligena striata* and *A. laevis* mentioned but without description or illustration. — H. C. Lea, Trans. Amer. Philos. Soc., New Ser., Vol. 9, p. 238, December, 1846. *Aligena striata* and *A. laevis* described and illustrated. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1175, 1900. "Type, *A. striata* Lea." — Gardner, U. S. G. S., Prof. Paper 199A, p. 87, 1943. Type as designated by Dall. — Harry, Veliger, Vol. 11, No. 3, p. 164, 1969. Earlier designations cited.

Type species (by subsequent designation, Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1175, 1900). — *Aligena striata* H. C. Lea, Trans. Amer. Philos. Soc., Ser. 2, Vol. 9, p. 238, pl. 34, fig. 13, December, 1846. "From the Tertiary of Petersburg, Virginia." Dall (Proc. U. S. Nat. Mus., Vol. 21, No. 1177, p. 877, 1899) cited *Abra aequata* Conrad as the "typical species" of *Aligena* but that species was not included with the taxa originally referred to *Aligena* by Lea. Later, Dall placed *Aligena striata* Lea in the synonymy of *Aligena aequata* (= *Amphidesma aequata* Conrad, 1843). See Dall, 1900, p. 1175, pl. 24, figs. 8, 8a, 8b. Miocene of southeast Atlantic states, also Caloosahatchie Pliocene of Florida.

Range. — Miocene to Recent. Recent in temperate and tropical waters, usually from low tidal zone to 112 meters (61 fathoms). One species was reported by Dall from 3680 meters (2012 fathoms).

Description. — The characteristic of this group is the possession of a rounded triangular inflated shell with only a single small anterior tooth under the beaks, separated by a gap from the surface of attachment, under the posterior dorsal margin, of an elongate internal resilium carrying a lithodesma. The pallial line is simple, and the cardinal of the left valve more feeble than the other. (Dall, 1900.)

Remarks. — *Aligena* is here recorded for the first time from beds of Pliocene age in the west American states. This genus is well known in beds of Miocene age in the Atlantic states and has been reported from the Vienna and Paris basins.

Four Recent species referable to *Aligena* have been described from west American waters two of which have been reported from beds of Pleistocene age.

Dall (1900, p. 1175) believed that a close relationship existed between *Aligena* and *Spaniodon* Reuss (654), but Cossmann and Peyrot (655) believed it to be close to *Spaniorinus* Dall (656).

Harry (657) recently reviewed the living species of *Aligena*. He mentioned that some species of this genus are probably polychaete associates.

Aligena diegoana n. sp.
Plate 44, Figures 1, 6;
Plate 45, Figures 6, 7, 10, 11, 13

Description. — Shell roundly quadrangular, rather large for the genus, convex, the anterior is longer and

Key to Genera and Subgenera of Kelliidae

A. Left valve with 1 cardinal tooth; lateral teeth lacking . . . . . *Aligena*

B. Left valve with 2 cardinal teeth; lateral teeth present

a. Valves smooth; periostracum present . . . . . *Kellia*

aa. Valves radiately striated or punctate; periostracum lacking

b. Ventral margin of hinge plate bisected by the resilum . . . . *Bornia*

bb. Ventral margin of hinge plate not bisected by the resilium. . *Temblornia*

narrower than the posterior end; beaks small, prosogyrate, situated a little posterior to the middle of the valves; lunular area gently depressed; anterior dorsal margin sloping moderately steeply to the anterior and which is rounded and slightly attenuated, posterior dorsal margin sloping gently downward and merging imperceptibly into the broadly rounded posterior end, ventral margin very slightly rounded; exterior of valves sculptured only with lines of growth; hinge of right valve with a large, slightly twisted tooth beneath the beak, behind this a subtriangular, elongated ligamental pit; in front of the tooth there is an elongated depression which receives a projection of the opposite valve and fades out as a slight groove along the margin; hinge of left valve (paratype) with a large, tooth-like projection of the lunular margin, behind this a very small cardinal lamella (lacking on some specimens) below the beak, and back of this the ligamental pit. Dimensions of holotype, a right valve, length 7.9 mm, height 6.1 mm, convexity (one valve), (approximately) 2 mm.

Type Specimen. — Holotype and paratypes in Los Angeles County Museum. From Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U. S. G. S. topog. map, San Ysidro quad., ed. 1943).

Occurrence in San Diego Fm. — L.A.M. 305A, 318, 319.

Remarks. — This species is represented in the present collections by more than 30 single valves. These vary in outline, some are more rounded in outline than others, and in some specimens the ventral margin is nearly straight. A broad, low, medial sulcus is present on some valves.

The cardinal tooth in the left valve of *A. diegoana*, n. sp., is reduced to a thin lamella, or is absent on some specimens. The development of a tooth-like projection of the lunular margin which fits into a groove on the opposite valve appears to be compensatory for the reduction of the cardinal and augments the interlocking of the hinge area.

The general outline of *Aligena diegoana*, n. sp., is somewhat similar to that shown in an illustration of a Recent specimen from off the west coast of Lower California which Harry (1969, fig. 16) referred to *Aligena cerritensis* Arnold. The type specimen of *A. cerritensis* is obliquely ovoid in outline.

The general shape of some valves of the new species is similar to that of *Aligena aequata* var. *nuda* Dall from Miocene strata in Maryland, as illustrated by Glen (658). The new species also bears a resemblance to the east American *Aligena laevis* H. C. Lea (659) which occurs in strata of Miocene and Pliocene age. The west American species is more quadrate in outline and the hinge of the right valve apparently has a deeper, more trigonal ligamental pit.

The species described as *Aligena redondoensis* by T. Burch (660) was placed by Harry (1969, p. 179, figs. 34-37) in a new genus *Tomburchus* and assigned to the family Thyasiridae.

A species from British Columbia was described as *Aligena (Odontogena) borealis* by Cowan (661). This boreal species is the type of *Odontogena* to which Harry (1969, p. 179) assigned generic rank.

GENUS *KELLIA* TURTON

Kellia Turton, Conchylia Insularum Britannicarum, pp. XIX, XXV, 56, 1822. Species cited, *Kellia suborbicularis* Montagu, *Cardium rubrum* Montagu and *Cardium laeve* Walker (in synon.) — Jeffreys, Brit. Conch., Vol. 2, p. 222, 1863. — Kobelt, Illustr. Conchylienbuch, Bd. 2, Lief, 10-11, p. 351, 1881. "Typus is *Kellia suborbicularis* Montagu (Taf. 103, Fig. 3) aus den europäischen Meeren." — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 87, 1958. "Type species by subsequent designation, Reclúz". . ., 1844. — Olsson, Mollusks of the Tropical Eastern Pacific, (Paleo. Res. Inst., Ithaca, New York), p. 231, 1961. Type species as designated by Reclúz.

Chironia Deshayes, Rev. Zool. par la Soc. Cuvierienne, Ann. 1839, p. 357. Sole species, "*Chironia Laperousii.*"

Kellyia Turton (emend.), Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. du Roussillon, Tome 2, Fasc. 6 (Pelecypoda, Fasc. 19), p. 235, 1892. "Il faut donc que le *Mya suborbicularis* soit conservé comme type du genre *Kellyia.*"

Kellya Turton, Thiele, Handbuch Syst. Weichtierkunde, Bd. 2, p. 870, 1934. [Not all the synonymy.]

Type species (by subsequent designation, Reclúz, Rev. Zool., Soc. Cuvierienne, Vol. 7, p. 295, 1844). — "Le type de son *Kellia*, celui seul qui correspond au caractère de son genre, le *Kellia suborbicularis* . . ." [= Mya *suborbicularis* Montagu, Test. Britannica, Pt. 1, p. 39, 1803. "We first discovered this species in hard limestone at Plymouth." "It is sometimes dredged up in Salcombbay." Illustrated in Suppl., pl. 26, fig. 6, 1808. — Turton, Conch. Ins. Brit., p. 57, p. 11, figs. 5, 6, 1822 (as *Kellia suborbicularis*). "In limestone and old bivalves." — Forbes and Hanley, Hist. Brit. Moll., Vol. 1, pl. 0, fig. 4 (animal), 1853; Vol. 2, p. 87, pl. 18, figs. 9, 9a, 9b, 1853 (as *Kellia suborbicularis).* Loire basin, France, middle Miocene. — Tebble, British Bivalve Seashells [British Museum (Nat. Hist.)]. p. 83, text fig. 37a, b, c, 1966 (as *Kellia suborbicularis.*)

Range. — Eocene to Recent. Recent, widespread in all seas from intertidal zone to 2772 meters (1515 fathoms).

Description. — Shell small or of medium size, thin, glassy, white, suborbicular and strongly convex, surface usually smooth, polished or with fine or strong, concentric lines of growth. The umbones are prominent, submedian, the small beaks incurved and prosogyrous. Hinge plate narrow, with a wide notch in the middle bordered on each side by a small tooth, the anterior one shaped like a cardinal tooth, the posterior one placed more distantly; the left valve has two small divergent cardinal teeth with a socket or pit between them, the right valve has a single cardinal only; both valves have a flattened tooth at the posterior end of the median pit. Ligament is wholly internal, the tensilium small, narrow, lying below the margin and above a narrow nymphal lamina which distantly ends in a tooth, the resilium also elongated in form and attached to a linear groove in the roof of the subumbonal cavity. In some species, the surface is covered by a glossy, yellowish periostracum. (Olsson, Mollusks of the Tropical Eastern Pacific. Paleo. Res. Inst.: Ithaca, New York, p. 231, 1961.)

Remarks. — There have been differences of opinion

by various authors (662) concerning the spelling of this generic name but most authors adhere to the original orthography, *Kellia*.

The members of *Kellia* often nestle in holes in rock or in pilings. Some species attain a length of 33 mm (663) but most of them are shorter. Oldfield (664) discussed the functional morphology of *K. suborbicularis*.

In western North America, three species referred to *Kellia* have been described from beds of Eocene age, one in the Oligocene, and two range from Pliocene to Recent. The genus is here reported from the San Diego Formation for the first time.

Kellia laperousii Deshayes
Plate 44, Figures 11, 19

Chironia laperousii Deshayes, Rev. Zool., Soc.Cuvierienne, Année 1839, p. 357, issued December, 1839. — Deshayes, Mag. de Zool., Ann. 1840, Livr. 5, Moll., pl. 12, 4 figs. — Chenu, Man. de Conchyl., Vol. 2, p. 126, figs. 600, 601, 1862.

Bornia luticola Valenciennes, Voy. Venus, Atlas,Moll., pl. 24, figs. 7, 7a, 7b, 1846. [No description nor locality.]

Kellia laperousii Deshayes, Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 643, issued August, 1864. Cited from several localities from Vancouver Island, British Columbia, to California. Reprint in Smithsonian Misc. Coll., No. 252, p. 129, 1872. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 137, pl. 18, figs. 1, 1a, 1903. Pliocene to Recent. San Pedro and San Diego, California, Pleistocene. — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 39, pl. 6, fig. 2; pl. 37, fig. 4, 1924. "Bering and Pribilof Islands, Bering Sea, to San Diego, Calif." — Yonge, Univ. Calif. Publ. Zool., Vol. 55, No. 11, pp. 451-453, fig. 1 (in text), 1951. — Morris, A Field Guide to Shells of the Pacific Coast and Hawaii. (Houghton Mifflin Co., Boston) p. 38, pl. 10, fig. 7, 1952. — Howard, Wasmann Jour. Biol., Vol. 11, No. 2, p. 238, fig. 3 (p. 237), 1953.

Kellya laperousei Deshayes, Fischer, Man. de Conchyl., Fasc. 11, p. 1026, pl. 19, fig. 11 ("Californie"), 1887.

Kellia laperousei Deshayes, I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 131, pl. 10, fig. 2; pl. 33, fig. 4, 1924. "Bering Sea and Pribiloff Islands to San Diego, California." Also San Pedro, Pliocene; and San Pedro and San Diego, California, Pleistocene.

Chironia suborbicularis (Montagu) variety *laperousii* Deshayes, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 300, pl. 14, figs. 19a, 19b, 1931. [Not all the synonymy.] Pleistocene and Recent.

Type specimen. — Dr. André Franc informed us (written communication, October 22, 1964) that two valves labeled "Type" are in the collection of the Laboratoire de Malacologie, Muséum National d'Histoire Naturelle (Paris) but that it is uncertain whether or not these represent the type specimen.

Type locality. — No locality cited originally.

Range. — Middle Pliocene to Recent. Recent from Bering Sea and Pribilof Islands to Tiburon Island in the Gulf of California, from intertidal zone to 393 meters (215 fathoms).

Occurrence in San Diego Fm. — L.A.M. 107, 305, 305A.

Original description. — Testa ovato transversa, subequilaterali, inflato turgida, laevigata; alba sub-epidermide viridi lutescente, umbonibus minimis, acutis, oppositis. (Deshayes.)

Remarks. — Several valves here referred to *Kellia laperousii* are present in the collections of the Los Angeles County Museum from near the Mexican boundary. One of the largest of these is 8.5 mm long and 6.9 mm high. One very convex right valve from Loc. 107 (LAM), retaining most of the shell material, apparently the same species, is 17 mm long, 13.5 mm high, convexity, approximately 5 mm. These valves closely resemble Recent specimens, in various collections, identified with *K. laperousii*. A large Recent specimen in the collections of the California Academy of Sciences, collected by W. W. Schneeble in Monterey Bay, California, at a depth of 40 feet, is 31 mm long, 25 mm high, the convexity (both valves together) 29 mm.

This is the first record of the occurrence of this species in the San Diego Formation. It has been reported from beds of similar age, the Cebada Member of the Careaga Formation, in the Santa Maria district in Santa Barbara Co.

Some of the small valves, about 3 mm long, from near the Mexican boundary, bear a close resemblance to *K. suborbicularis* Montagu, originally described from England. However, there is so much variation in shape in a series of Recent specimens of *K. laperousii*, some elongated, some subcircular, that we assign all the fossil valves in the present collections to that species. Howard (1953) discussed the early stages of development of this species.

Kellia suborbicularis Montagu (665), reported to range from middle Miocene to Recent in Europe, has been reported from beds of Pliocene age in Los Angeles by Soper and Grant (666), by others from beds of Pleistocene age in southern California and in the Galápagos Islands. It was cited by Laws (667) as occurring in beds of Pleistocene age in New Zealand, and from beds of Pleistocene age from widespread areas such as Morocco, Patagonia and New Zealand. It has been reported living in nearly all temperate and tropical seas. Some authors have considered it to be a bipolar species. Marie Lebour discussed the life history of this species (see Jour. Mar. Biol. Assoc. U. K., Vol. 22, No. 2, pp. 447-451, text-fig. 1 (a-h, j-m), 1938).

The question as to whether this species is cosmopolitan or whether several closely related forms are involved has been discussed by several authors. E. A. Smith (668) stated that shells of this species could not be separated with certainty from allied forms. More recently Soot-Ryen (669), in a discussion of Antarctic shells similar to *K. suborbicularis*, stated that the relationship of such forms is still unsettled but he suggested that probably a number of nearly related species are concerned in this problem.

None of the fossils from the San Diego Formation is as circular in outline as the syntypes of the Recent west American *K. laperousii chironii* Carpenter illustrated by Palmer (670).

Kellia rotunda Carpenter was described as much larger than *K. suborbicularis* and nearly round in outline. The type of this species was not found by Palmer (671) and it generally has not been cited in recent years.

GENUS *BORNIA* PHILIPPI

Bornia Philippi, Enumeratio Molluscorum Siciliae, Vol. 1, p. 13, 1836. — Gardner, U. S. G. S., Prof. Paper 199-A, p. 82, 1943 [January, 1944]. Type as designated by Stoliczka. — Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 92, 1953. Type as designated by Stoliczka.

Type species (designated by Stoliczka, Mem. Geol. Surv. India, Paleo. Indica, Ser. 6, Vol. 3, Cretaceous Fauna of South India, Vol. 3, pp. XIX, 266, 1870).— "type, *B. corbuloides*, Phil." [*Bornia corbuloides* Philippi, 1836, p. 14, pl. 1, fig. 15. "Habitat Cataniae, Panormi, non rara." — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 6 (Pelecypoda, Fasc. 19), p. 235, pl. 39, figs. 1, 2, 1892 (as *Kellyia sebetia* Costa; as of Cantraine on expl. to plate). Mediterranean and Adriatic; Portugal. Miocene to Recent. — Cossmann and Peyrot, Conch. Néogéne l'Aquitaine, Vol. 1, Livr. 3 (extr. from Act. Soc. Linn. Bordeaux, Vol. 65), p. 569, fig. 109 (hinge of *Bornia sebetia*), 1911.]

Range. — Early Eocene to Recent.

Description. — Shell usually small, subtrigonal to subelliptical, compressed or weakly convex. Surface usually smooth, polished or faintly ribbed and striated. Ligament comprising a feeble external portion, more or less amphidetic and a subumbonal, internal resilium without a lithodesma. Hinge: left valve with a long, strong, posterior lateral tooth and a smaller, less distant anterior lateral, together with a small cardinal closely adjacent to it; in the right valve with strong lateral sockets and a small, anterior cardinal socket. (Olsson and Harbison.)

Remarks. — The shell of this genus differs from that of *Kellia* in that the surface is radially striate or punctate, at least in part, in lacking a periostracum, and in the narrower hinge in which the posterior cardinal of the left valve is greatly reduced in size.

Five Recent species assigned to *Bornia* have been described from the Panamic region and one from southern California.

SUBGENUS *TEMBLORNIA* KEEN

Temblornia Keen, Trans. San Diego Soc. Nat. Hist., Vol. 10, No. 2, p. 38, December 30, 1943.

Type species. — "Type: *Donax triangulata* Anderson and Martin, 1914." [Proc. Calif. Acad. Sci., Ser. 4, Vol. 4, p. 63, pl. 3, fig. 9, December 30, 1914 ". . . on west bank of a small canyon 1 1/4 miles northeast of Barker's ranch house, Kern County, California." Miocene. — Keen, 1943, p. 39, pl. 3, figs. 6, 7 (as *Bornia (Temblornia) triangulata).*

Range. — Middle Miocene to middle Pliocene.

Description. — Resembling *Bornia* in outline, with radial sculpture on anterior and posterior slopes; differing from *Bornia*, sensu stricto, in the structure of the hinge; resilifer small and shallow, ventral margin of hinge plate entire, not bisected as in *Bornia*, *s. s.*, by the insertion of the resilium; hinge teeth well developed, consisting of two cardinals and a posterior lateral in the left valve, two cardinals in the right. (Keen.)

Remarks. — Keen called attention to the similarity of this subgenus to *Semeloidea* Bartram and Powell, which has as type *S. donaciformis* Bartram and Powell (Trans. New Zealand Inst., Vol. 59, Pt. 1, p. 158, pl. 29, figs. 49, 50, 1928) from "Kaawa Creek, New Zealand, late Tertiary."

Compared to *Semeloidea*, the lower margin of the hinge plate of *Temblornia* is more arched, the posterior cardinal is less curved and the radial riblets, externally, are more numerous and finer.

Three species of this subgenus have been reported, the type species from strata of middle Miocene age in California, one of Miocene age in Ecuador (672) and one as yet undescribed species in the Gatun Formation of Miocene age in the Panama Canal Zone. To these we add a new species from the San Diego Pliocene.

Bornia (Temblornia) frankiana n. sp.
Text Figure 11

Description. — Shell, a right valve, small, elongately trigonal, moderately inflated, nearly equilateral, slightly longer posteriorly; anterior and posterior margins nearly straight, near the ends rounding into the ventral margin; 10 rounded radial ribs on the anterior end just posterior to the margin and 7 similar ones, somewhat flattened, on the posterior end, the ribs are faint dorsally but become gradually more strongly developed toward the ventral margin; ribs separated by interspaces which are a little wider than the ribs and in these, toward the ventral margin, lines of growth are accentuated (perhaps a result of erosion); remainder of the valve smooth except for somewhat irregular lines of growth; hinge with 2 well developed cardinal teeth; interior of anterior and posterior ends of valve crenulated and slightly denticulated corresponding to the exterior sculpture. Length 6.5 mm, height 4.1 mm.

Text Fig. 11. *Bornia (Temblornia) frankiana* Hertlein and Grant, new species. Holotype (Los Angeles County Museum), right valve from Loc. 305C (LAM), near the Mexican boundary, southwestern San Diego County; Pliocene. Length 6.5 mm. A. View of exterior. B. View of interior. (Drawn by Dorothy Ludlow.)

Type specimen. — Holotype, a right valve, Invertebrate Paleontology Collection, Los Angeles County Museum.

Type locality.—Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base

and Meridian (see U. S. G. S. topog. Map, San Ysidro quad., rev. 1953.) San Diego Formation, middle Pliocene.

Range. — Known only from the type locality.

Remarks. — *Bornia (Temblornia) frankiana*, new species, differs from the two other described species of *Temblornia* in its more elongately trigonal outline and in the nearly straight anterior and posterior margins.

This species is named for the late Frank Stephens, Curator Emeritus, San Diego Society of Natural History, who aided us on many occasions during field collecting in the San Diego area.

FAMILY MONTACUTIDAE CLARK (673)

Shell generally small, ovate to oblong, thin or heavy, depressed or convex, the anterior side the longer. Ligament mostly internal, subumbonal or lodged in an elongated, oblique resilifer in the hinge margin behind the beaks. Surface smooth or with concentric growth lines and sometimes radial undulations. Habit of most species appears to be commensal. (Olsson, Mollusks of the Tropical Eastern Pacific, Paleo. Res. Inst.: Ithaca, New York, p. 233, 1961.) Eocene to Recent.

Key to Genera of Montacutidae

A. Right valve with 2 cardinal teeth . . *Pristes*

B. Right valve lacking cardinal teeth . . *Mysella*

GENUS *MYSELLA* ANGAS

Mysella Angas, Proc. Zool. Soc. London for 1877, p. 176, issued August, 1877. Sole species: *Mysella anomala* Angas. — Cotton and Godfrey, The Molluscs of South Australia (issued by the South Australian Branch of the British Science Guild: Adelaide), p. 224, 1938. "Genotype — *M. anomala* Angas." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 233, 1961. "Type species by monotypy, *M. anomala* Angas. Australian waters."

Rochefortia Velain, Compt. Rend. Acad. Sci. (Paris), Vol. 83, p. 285, July 24, 1876. *Rochefortia australis*, a *nomen nudum*. — Velain, Arch. Zool. Expér. Gen. (Paris), Vol. 6, p. 132, no earlier than November 12, 1877. — J. Q. Burch, (ed.), Min. Conch. Club South. California, No. 110 p. 1, June, 1951. — see K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 88, footnote 36, 1958. — Keen, Treatise on Invertebrate Paleontology (Geol. Soc. Amer. and Univ. Kansas Press), Pt. N. Moll. 6, p. N531, 1969. Type: *R. australis* Velain, figs. 3a, 3b. Saint Paul Island, Recent.

Type species (by monotypy). — *Mysella anomala* Angas [Proc. Zool. Soc. London for 1877, p. 176, August, 1877. "Hab. Shark Island, Port Jackson, in black mud, in 12 fathoms." — Laseron, Rec. Australian Mus., Vol. 24, No. 2, p. 18, figs. 23, 23a, 23b, 1956. New South Wales, Australia. — Keen, 1969, figs. 9a, 9b.]

Range. — Middle Miocene to Recent. Widely distributed in present seas, from 11 to 320 meters (to 175 fathoms).

Description. — Shell triangularly ovate, anterior end longer, sculpture concentric; left valve with a large, diverging, flattened tooth posterior to the triangular resilifer; the anterior margin of the resilifer is thickened and margined to simulate a transverse tooth; in front of this is a small socket; right valve with the hinge margin on each side of the umbo produced, which is overlapped by the hinge line of the opposite valve; the posterior tooth-like edge interlocks above the cardinal tooth of the left valve, and the anterior which is shorter, is received in the socket in front of the ridge-like edge of the resilifer. These tooth-like margins of the right valve represent cardinal rather than lateral teeth. (Cotton and Godfrey.)

Remarks. — Laseron (1956, p. 18) pointed out that a feature common to all species of *Mysella* "is that the horizontal lateral processes in the right valve are caused by a peculiar infolding of the dorsal margin on either side of the umbos, and are in no sense lateral teeth as generally understood."

Fossil and Recent species attributed to this genus have been recorded from various regions. The genus has been reported from Pliocene to Recent in western United States. About 12 species referred to "*Rochefortia*" or *Mysella* have been reported living in west American waters between the Aleutian Islands, Alaska, and the Gulf of California, and others have been described from more southern waters.

Some authors treat *Mysella* and *Rochefortia* (674) as separate genera. Others place *Rochefortia* either as a subgenus of *Mysella* or in the synonymy of that genus.

The species of small bivalves belonging to *Mysella* and related genera, will remain difficult to identify specifically until careful comparative studies are made and adequate illustrations are available.

Dell (675) discussed some of the Antarctic and subantarctic species of *Mysella*.

Mysella tumida Carpenter
Plate 44, Figures 2, 3, 4, 5, 7, 8, 12;
Plate 45, Figures 5, 8, 9, 12

Tellimya tumida Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 602, 611, 643, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 88, 97, 129, 1872.

Mysella tumida Carpenter, Dall, Proc. U. S. Nat. Mus., Vol. 21, No. 1177, pp. 881, 892, pl. 87, fig. 7 ("type specimen." "California."), 1899. "Alaska Peninsula and south to San Diego, California," Recent. — Abbott, Amer. Seashells (D. Van Nostrand Co.), p. 397, fig. 80b, 1954. "Alaska to Lower California." — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 88, pl. 7, figs. 8-12, 1958. Earlier records cited.

Rochefortia tumida Carpenter, Dall, U. S. Nat. Mus., Bull. 112, p. 37, 1921. "Shumagin Islands, Alaska, to San Diego, California." — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 40, 1924. "Orcas and Turn Islands, Wash., along shore." Shumagin Islands, Alaska, to San Diego, California. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 132, pl. 54, figs. 11-14, 1924. Same range as in preceding reference.

Type specimen. — No. 5242, United States National Museum.

Type locality. — Indicated as from Puget Sound and the neighborhood; Vancouver Island, Straits of San Juan de Fuca, and adjoining shores of Washington territory;

also the region between San Diego and San Pedro, California. "The holotype bears the label 'Puget Sound, Kennerley' " (Palmer, 1958.)

Range. — Middle Pliocene to Recent. Recent from the Shumagin Islands, Alaska, to Scammon Lagoon, Lower California, Mexico, shore to 88 meters (48 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A, 318.

Original description. — "Between *bidentata* and *substriata*: ossicle minute." (Carpenter, 1864.)

Supplementary description. — T. t. subtriangulari, subovatâ, laevi, solidiore, tumidiore, valde inaequilaterali; cinereâ, epidermide pallide olivaceâ, concentrice striatâ indutâ; marginibus dorsalibus subrectis, ventrali excurvato: intus, dentibus cardinalibus valvâ sinistrâ validissimis, curtis, extantibus, postico longiore, valvâ dextrâ callositatibus marginalibus, dentibus nullis; cartilagine validiore, ossiculum parvum in medio gerente; cicatricibus adductoribus à cardine valde remotis. Long. .115, lat. .125, alt. .06. (Carpenter, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, p. 58, 1865.)

Remarks. — Many valves here referred to *Mysella tumida* are present in the collections from near the Mexican boundary. These are small, the largest about 3 mm long, rounded trigonal to trigonally ovate and gently convex. The left valve, as mentioned by Palmer, has two cardinal teeth which are quite large for the size of the shell.

This is the first record of the occurrence of this species in the San Diego Formation. Woodring (676) reported it from the Graciosa Member of the Careaga Sandstone in the Santa Maria district in beds of late Pliocene age.

The fossils from San Diego are quite similar to specimens from Puget Sound in the collections of the California Academy of Sciences which were identified by T. S. Oldroyd as "*Rochefortia*" *tumida*. Some of the specimens in the present collection are more elongate than others. Similar forms were illustrated by Addicott (U. S. G. S., Prof. Paper 523-C, p. C4, pl. 4, figs. 12, 13, 1966) under the name of "*Mysella* cf. *M. tumens*" from beds of Pleistocene age at Point Año Nuevo, San Mateo Co., California.

The species described by Dall as *Mysella pedroana* (677) is elongate in outline but the hinge was described as "feeble." The illustration of the type shows the hinge to be quite different from that of *M. tumida*. Another elongate species, was described but not illustrated, under the name of *Rochefortia golischi* Dall (678). MacGinitie (679) discussed the shell characters of *M. pedrona* and *M. golischi* and stated that the two are distinct species. She mentioned that on *M. pedroana* the umbones are nearer the anterior end and that the posterior end (more elongated than the anterior end) slopes more abruptly downward than that of *M. golischi*.

GENUS *PRISTES* CARPENTER

Pristes Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 611, 643, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 97, 129, 1872. Sole species *Pristes oblongus* Carpenter. — Vokes, Jour. Paleo., Vol. 30, No. 3, p. 768, May, 1956. — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 89, 1958. "Type species by monotypy *Pristes oblongus* Carpenter."

Not *Pristis* Linck, 1790. Not *Pristis* Müller and Henle, 1837.

Pristiphora Carpenter, Proc. Calif. Acad. Nat. Sci., Vol. 3, p. 210, February, 1866.

Not *Pristiphora* Latreille, 1810. Hymenoptera.

Serridens Dall, Proc. U. S. Nat. Mus., Vol. 21, No. 1177, p. 880, June, 1899. A new name for *Pristiphora* Carpenter, 1866. Not *Pristiphora* Blanchard, 1835.

Type species (by monotypy). — *Pristes oblongus* Carpenter.

Range. — Middle Pliocene to Recent. Recent, intertidal, commensal with *Ischnochiton*.

Description. — Shell oval, with two diverging teeth in each valve, the anterior being conspicuously shorter than the posterior, sulcated near the beaks, ligament situated in a groove between them. (Tryon, G. W., Jr., Structural and Systematic Conchology, Vol. 3, p. 220, 1884.)

Remarks. — This genus of small leptonids is represented solely by the type species which lives only in eastern Pacific waters. Vokes (1956), and K. V. W. Palmer (1958), discussed the nomenclatorial problems concerning the genus name *Pristes*. This genus is reported here for the first time from beds of Pliocene age.

Pristes oblongus Carpenter
Plate 44, Figures 9, 10, 13, 14

Pristes oblongus Carpenter, Rept. Brit Assoc. Adv. Sci. for 1863, pp. 611, 643, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 97, 129, 1872. P. 611 (97). "S. Diego." P. 643 (129), "D" [=] "The region between S. Diego and S. Pedro." — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 89, pl. 9, figs. 11-13, 1958. "San Pedro to San Diego, California [San Pedro] (type); Monterey, California to San Hipolito Point, Lower California (Burch)."

Pristiphora oblonga Carpenter, Proc. Calif. Acad. Sci., Vol. 3, p. 210, February, 1866. "Hab. San Diego; 1 worn valve among shell washings. Cooper."

Serridens oblonga Carpenter, Dall, Proc. U. S. Nat. Mus., Vol. 21, No. 1177, p. 880, 1889. "San Pedro, California" — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 135, pl. 54, figs. 5, 6, 7, 8, 1924. "Type locality, San Diego, California." "Range: Puget Sound to Coronado Islands, Lower California." — J. Q. Burch, Min. Conch. Club South. California, No. 40, p. 16, October, 1944. Monterey, California, to San Hipolito Point, Lower California. Commensal with *Ischnochiton conspicuus* Carpenter, and *I. magdalenensis* Hinds.

Type specimen. — Lectotype No. 15592, United States National Museum (Palmer, 1958).

Type locality. — "S. Diego" and "The region between San Diego and San Pedro," Carpenter, 1864. San Pedro, California, selected as type locality by Palmer (1958).

Range. — Middle Pliocene to Recent. Recent from Monterey, California, to San Hipolito Point, Lower California, commensal with *Ischnochiton conspicuus* Carpenter, *I. heathiana* Berry and *I. magdalenensis* Hinds.

Occurrence in San Diego Fm. — L.A.M. 305, 305A.

Original description. — "Like *Tellimya*, with long marginal teeth, serrated near hinge." (Carpenter, 1864.)

Supplementary description. — P. t. oblongâ, parvâ, subquadratâ, valde inaequilaterali; parte anticâ fere nulla, marginibus, dorsalibus subrectis, fere rectangulatis, ventrali parum excurvato, postico rotundato; umbonibus antie flectis; lunulâ parvâ, concavâ: intus, v. sinistr., dent. lat. post. per totam longitudinem dorsalem decurrente, parte cardinali acutâ, alte transversim sulcatâ, ant. secundum lenulam incurvato curto, serrato; cicatr. adduct. sub fines dentium sitis. Long. 0.14, lat. 0.10, alt. ?0.06. (Carpenter, 1866.)

Remarks. — Nine single valves of *Pristes oblongus* are present in the collections from near the Mexican boundary. This is the first record of its occurrence in the San Diego Formation. Previously it was reported as a fossil by Valentine (680) from beds of Pleistocene age at Crown Point, San Diego, California.

This small, elongate leptonid was reported from Puget Sound by I. S. Oldroyd, 1924, but later authors have cited it as ranging northward only to Monterey, California. It lives commensal with chitons.

FAMILY SPORTELLIDAE DALL (681)

Shells are generally small, ovate to narrowly elongate, thin and usually white in color. The umbones are usually prominent, sometimes near the middle, or much closer to the anterior end. Hinge generally with one or two large teeth in each valve. Ligament largely external, occasionally showing a small, internal resilium. Surface smooth or roughtened with growth threads, sometimes heavily pustulated. (Olsson, Mollusks of the Tropical Eastern Pacific, (Paleo. Res. Inst.: Ithaca, New York), p. 241, 1961.) Late Jurassic (682) (Sequanian); Paleocene to Recent.

GENUS *BASTEROTIA* MAYR IN HÖRNES

Harlea Gray, Synop. Brit. Mus., 1842, p. 78 [no species cited]. See E. A. Smith, Proc. Zool. Soc. London, April 1, 1890, p. 303.

Eucharis Reclúz, Jour. de Conchyl., Vol. 1, p. 164, 1850. Type, *Corbula quadrata* Hinds.

Not *Eucharis* Latreille, 1804.

Basterotia Mayr in Hörnes, Verhandl. K. K. Zool.-Bot. Gesell. Wien, Bd. 9, Abh. p. 71, 1859. *Basterotia corbuloides* Hörnes cited and illustrated. — Woodring, Carnegie Inst. Washington, Publ. No. 366, p. 190, 1925. "Type (by monotypy). — *Basterotia corbuloides* Mayer." [The genus placed in the family *Basterotidae.*] — Hertlein and Strong, Zoologica, Vol. 31, Pt. 4, p. 137, 1947. "Type (by monotypy): *Basterotia corbuloides* Hörnes." — Olsson Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 242, 1961. "Type species by monotypy, *Basterotia corbuloides* Hörnes."

Not *Basterotia* Bayle in Jousseaume, 1884. Gastropoda.

Type species (by virtual monotypy.) — *Basterotia corbuloides* Hörnes, 1859, p. 71, three figs., "Wiener Becken." Miocene. See also Hörnes, Abhandl. K. K. Geol. Reichsanst., Bd. 4, p. 40, pl. 3, figs. 11a-g, 1870. Various localities cited in Vienna Basin, Austria. Miocene.

Range. — Miocene to Recent. Recent in the eastern Pacific from the Gulf of California to Ecuador and the Galápagos Islands. Also Caribbean and Indopacific; from 11 to 1170 meters (6 to 640 fathoms).

Description. — Shell small, subquadrate corbuliform, with a sharp angle or carination running from the beak posteriorly. Valves convex and usually solid, white, the beaks prosogryate. Surface marked with fine concentric lines of growth and a sprinkling of fine or coarse granules. Ligament external, attached to a short, stout, plate-like nymph. Hinge with a large, hook-shaped cardinal tooth in each valve, bordered behind or in front by a deep socket; in the right valve, the socket lies in front of the tooth and in the left valve behind. There is no pallial sinus. (Olsson, 1961, p. 242.)

Remarks. — Four species referred to this genus have been reported from the late Cenozoic of the tropical eastern Pacific, one of which is Recent.

Lamy (683) listed 13 Recent species which he referred to *Basterotia.* Some of these were placed in other genera by later workers.

SUBGENUS *BASTEROTELLA* OLSSON AND HARBISON

Basterotella Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 97, November 6, 1953.

Type species (by original designation and by monotypy). — *Pleurodesma floridana* Dall [Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1630, pl. 57, fig. 30, October, 1903. "Pliocene marls of Shell Creek, Florida; long. 14.5 mm." See also Olsson and Harbison, 1953, p. 98, pl. 8, fig. 2; pl. 9, figs. 1, 1a (as *Basterotia (Basterotella) floridana.*) Florida, Pliocene].

Range. — Miocene to Recent. Recent in the eastern Pacific from the Gulf of California to Ecuador and the Galápagos Islands.

Description. — Like *Basterotia* in form, angled or carinate umbo, surface granulation and large, hook-shaped, subumbonal cardinal tooth, but differs in having both an internal and external ligament. Nymphal plate small and narrow, the resilial pit a small scar on its inner and lower face. (Olsson and Harbison, 1953.)

Remarks. — The shell of the type species of *Basterotella* bears scattered granules which are strongest near the anterior-ventral side. These granules are said to be present on the right valve of Caribbean members of this group, but may be lacking on the left valve. No such granules have been described as occurring on the valves of west American species assigned to this subgenus.

Four species described from the tropical and subtropical eastern Pacific have been assigned to *Basterotella.* Three species described from the Gulf of California region, have been reported as follows: one from strata of late Pliocene age, two from the Pleistocene and one of these Recent. An additional species living in Ecuador and the Galápagos Islands was described by Olsson.

This is the first record of *Basterotia*, subgenus *Basterotella*, from California.

Basterotia (Basterotella) hertleini Durham
Plate 57, Figures 6, 11

Basterotia hertleini Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 94, pl. 25, figs. 4, 11, August 10, 1950.

Basterotia (Basterotella) hertleini Durham, Emerson and Hertlein, Trans. San Diego Soc. Nat. Hist., Vol. 13, No. 17, p. 355, figs. 4g-j, 1964. Marquer Formation, Puerto Ballandra, Carmen Island, Gulf of California, Pliocene.

Type specimen. — Holotype No. 32274, University of California (Berkeley), Department of Paleontology, Type Collection.

Type Locality. — Loc. A 3670 (U. C.), "Upper Pliocene, Puerto Balandra, Carmen Island. From sands at left end of outcrop and below base of coral reef (loc. A3534)."

Range. — Middle and late Pliocene.

Occurrence in San Diego Fm. — L.A.M. 305C.

Original description. — Shell in general resembling *B. peninsulare* (Jordan) but more elongate and normally less inflated; subquadrate, moderately thin, ornamented by irregular concentric growth lines only; beaks not very prominent; an angulation running from umbo to posterior ventral margin; umbos situated about a fourth the length from the anterior end; a prominent projecting cardinal tooth in each valve, with adjacent deep "socket" anterior to it in right valve. Length 13.2 mm, height 7.8 mm, thickness 3.6 mm (one valve). (Durham.)

"This species may be distinguished from *B. peninsulare* (Jordan) by its greater length, greater width between the angulation and the posterior ventral margin, normally lesser inflation, and usually less sharp angulation." (Durham.)

Remarks. — One right valve of this species, 11 mm long and 7.3 mm high, is present in the collection from Loc. 305C (LAM) from near the Mexican boundary. It is similar to specimens of *Basterotia hertleini* from the type locality on Carmen Island in the Gulf of California.

The shell of *B. hertleini* is very similar to that of *B. ecuadoriana* Olsson (684), a Recent species described from Ecuador. In comparison to the Recent species the shell of *B. hertleini* is longer in proportion to the height, more convex, with a less expanded posterior dorsal area and a narrower anterior end.

The valve of *B. hertleini* from the San Diego Formation differs from *B. peninsularis* Jordan (685) in the particulars mentioned by Durham.

Olsson mentioned that the Recent species cited by Hertlein and Strong (686) under the name of *Basterotia peninsularis* from West Mexico, Nicaragua, and the Galápagos Islands, is probably referable to *B. ecuadoriana*. We have examined those specimens, and also some others (787) from the Gulf of California upon which records of *B. peninsularis* Jordan were based. The beaks of these are less elevated and more anteriorly placed than those on the species described by Jordan. This bears out Olsson's suggestion that *B. ecuadoriana* lives in the Gulf of California. The range of this species is from San Luis Gonzaga Bay, east coast of Lower California (and probably from the head of the Gulf), to Manta, Ecuador, and the Galápagos Islands.

The only other species of *Basterotia* described from the eastern Pacific is *B. californica* Durham (688) from strata of Pleistocene age in Lower California. Compared to the three other species, it is much longer in proportion to the height. Keen (1971, p. 145) placed both *B. californica* Durham and *B. ecuadoriana* Olsson in the synonymy of *B. hertleini*.

SUPERFAMILY LUCINACEA FLEMING (689)

Allen (690) discussed the form and adaptation to habitat of this superfamily, and Boss (Nautilus, vol. 82, No. 4, pp. 128-130, 1969) recently discussed the relationships of this group of mollusks.

FAMILY LUCINIDAE FLEMING (691)

Shells small or large, subcircular to suborbicular, generally equivalve, but occasionally somewhat inequivalve (*Miltha*), thin or heavy, in the latter case, the interior may be coarsely pustulose. Hinge when typical has two strong cardinal teeth and an anterior and posterior lateral tooth or its socket in each valve, the posterior lateral element placed distantly at the end of the ligamental scar; in other forms, the hinge may be degenerate to a greater or lesser degree, the cardinal teeth and sometimes the laterals become obsolete and often wholly lacking in the adult. The ligament is external, attached to a deeply immersed scar lying below the margin of the valve. Adductor scars of unequal size, the anterior scar typically much larger, divided, the lower segment narrow and elongated and free from the pallial line. The pallial line itself entire and placed near the margin. Ventral margin smooth or crenulated. Surface sculpture, formed by radial or concentric elements or a combination of both. Often with a scaly periostracum. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 206, 1961). Silurian to Recent.

Remarks. — Dall stated that the shell material of the members of this family is usually porcelaneous or chalky and the periostracum may be hardly discernible or may be scaly in character.

The largest member of the family Lucinidae, as mentioned by Cox (692), is the species described as *Lucina megameris* Dall from the late Eocene of Jamaica. A specimen studied by Cox is 280 mm long and 290 mm high, the inflation of the valves about 85 mm.

Chaven (693) discussed the classification of this family in several papers.

GENUS *LUCINA* BRUGUIÈRE

Lucina Bruguière, Encycl. Méth., Tabl. Vers, pls. 284, 285, 286, 1797. [Name and figures only. The illustrations identified later include *Lucina pensylvanica* Linnaeus, *L. jamaicensis* Lamarck and *L. edentula* Linnaeus.] — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 175, 1931. Type as designated by Schumacher.

Type species (designated by Schumacher, Essai Nouv. Syst. Habit. Vers Test., p. 165, 1817). — *Venus pensylvanica* as illustrated by Chemnitz, Syst. Conchyl. — Cab., Bd. 7, p. 12, pl. 37, fig. 394, 1784. "an den Stranden der westindischen Meere" and "von den Ufern der Dänischen westindischen Eylande." [*Venus pensylvanica* Linnaeus, Syst. Nat., ed. 10, p. 688, 1758. "Habitat in America septentrionali." Ref. to Argenville, Conch., pl. 24, fig. N. Also illustrated by Reeve, Conch. Icon., Vol. 6, *Lucina*, species 29, pl. 6, fig. 29, 1850. — Lamy, Jour. de Conchyl., Vol. 65, No. 2, p. 172, 1920. (Fig. of hinge.) — M. Smith, East Coast Mar. Shells (Edwards Bros.: Inc.), p. 46, pl. 15, figs. 1a, 1b, 1945.]

Range. — Jurassic to Recent. Recent in from 15 to 7,224 meters (8 to 3950 fathoms).

Description. — Shell orbicular in outline, moderately inflated, occasionally subglobose, valves closed, lunule usually well developed, no escutcheon, an oblique depressed area present along the posterior dorsal margin; sculpture of concentric lamellae or lines of growth, sometimes also with radial elements; hinge with cardinal teeth and sometimes with laterals or these may be obsolete; ligament semi-internal; anterior muscle impression elongated within pallial line, posterior impression oblong; pallial line entire.

Remarks. — Many of the west American species of *Lucina* have appeared, at times, in the literature associated with the generic name *Phacoides*. The name *Phacoides* was first used by Blainville in a vernacular sense in 1824 (see Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. 3, p. 180, 1930). Apparently, the first usage of it as a valid generic name was by Gray (Proc. Zool. Soc. London for 1847, p. 195) who placed it in the synonymy of *Lucina* with the type species "*Ven. jamaicensis.*" Some authors retain *Phacoides* as a subgenus of *Lucina* (Olsson, 1961, p. 208), others recommend its abandonment (see Chavan, 1937, p. 141; Keen, 1958, p. 93).

Lucina is widely distributed both geographically and geologically. It is well represented in the Cenozoic of western North America. Six species occur in the San Diego Formation.

At the present time there are numerous species living in the seas. Lamy (694) published a catalogue of the Recent species in the collections of the Museum National d'Historie Naturelle in Paris and the tropical west American species have been discussed by several authors (695).

SUBGENUS *HERE* GABB

Here Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 28, February, 1866. *Lucina (Here) richthofeni* Gabb included in original list of species. — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 180, 1930. Type as indicated by Stoliczka. — Chavan, Jour. de Conchyl., Vol. 81, No. 3, p. 202, 1937. Genotype, *Here richthofeni* Gabb.

Type species (designated by Stoliczka, Geol. Surv. India, Palaeo. Indica, Ser. 6, Cret. Fauna South. India, Vol. 3, pp. XIX, 251, 1871). — *Lucina (Here) richthofeni* Gabb [Geol. Surv. Calif., Palaeo., Vol. 2, p. 29, pl. 8, figs. 49, 49a, 49b, 1866. "Locality: San Fernando Valley, north of Los Angeles; Pliocene." — Stewart, 1930, p. 181, pl. 15, fig. 3; pl. 17, fig. 5, 1930. See also Chavan, 1937, p. 203, fig. 3].

Range. — Eocene to Recent. Recent from the intertidal zone to 132 meters (72 fathoms).

Original description. — Shell having all of the usual characters of *Lucina*, except that the lunule is very deeply excavated, penetrating the hinge-plate, and almost perforating it; bounded anteriorly by the anterior lateral tooth, and posteriorly by the cardinal teeth. (Gabb, 1866.)

Remarks. — This subgenus appears in the Eocene of Europe, South America, Florida, western North America, and probably in other regions. It is represented from Eocene (697) to Recent in the Cenozoic of western North America. One species occurs in the San Diego Formation.

The species of this group are characterized by their rounded subglobular form, very deep lunule, and well developed concentric sculpture.

Chavan (698) pointed out that *Here* differs from *Linga* de Gregorio (699) in possessing a very deep lunule which results in the dwarfing of the left anterior cardinal tooth and complete lack of a right anterior cardinal, and in possessing more elongated posterior lamellae. The two groups are quite similar, but for the present at least we have followed traditional classification in leaving *Here* as a subgenus of *Lucina*.

Illesca Olsson (700) described as a subgenus of *Here* differs in that the lunule is "entirely immersed into the hinge-plate and in both valves seems to have completely effaced the anterior cardinal."

In west American waters, *Here* is represented at the present time by a single species which ranges from San Pedro, California, to Mazatlan, Mexico.

Key to Genera and Subgenera of *Lucina*

A. Hinge with cardinal teeth but lacking laterals
  a. Valves equally convex; strong concentric lamellae . . . . . *Lucinoma*
  aa. Valves unequally convex; concentric sculpture of growth lines only . . . . . *Miltha*

B. Hinge with both cardinal and lateral teeth
  a. Surface with concentric sculpture only
    b. Shell globose; lunule very deeply impressed. . . . . *Here*
    bb. Shell moderately inflated; lunule not deeply impressed
      c. Lunule nearly equally divided between the two valves . . *Lucina s. s.* (696)
      cc. Lunule in greater part or almost entirely in the right valve. . . *Epilucina*
  aa. Surface with radial and concentric sculpture
    d. Radial and concentric sculpture strong, spiny; margin denticulate . . . *Lucinisca*
    dd. Radial and concentric sculpture feeble, unequal, margin smooth . . . . . *Parvilucina*

Lucina (Here) excavata Carpenter
Plate 46, Figures 1, 2, 3

Lucina excavata Carpenter, Cat. Mazatlan Shells Brit. Mus., p. 98, November 1855. Mazatlan, Mexico. — Brann, Illustrations to "Catalogue of the Collection of Mazatlan Shells" by Philip P. Carpenter (Paleo. Res. Inst.: Ithaca, New York), pp. 13, 37, pl. 12, fig. 140, 1966. — Keen, Veliger, Vol. 10, No. 4, p. 396, pl. 56, fig. 23, 1968.

Lucina (Here) richthofeni Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 29, pl. 8, figs. 49, 49a, 49b, February, 1866. "Locality: San Fernando Valley, north of Los Angeles; Pliocene. Collected by Baron Richthofen."

Phacoides (Here) richthofeni Gabb, Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, pp. 810, 827, pl. 40, figs. 7, 9, 1901. "Catalina Island to Gulf of California, in 15 to 66 fathoms."

Phacoides richthofeni Gabb, Keep, West Coast Shells (The Whitaker & Ray Wiggin Co.: San Francisco), p. 69, fig. 45, 1911. "Catalina Island, Long Beach, and southward." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 174, 182, 1912. "San Diego - Purisima."

Lucina (Here) excavata Carpenter, Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 181, pl. 15, fig. 3; pl. 17, fig. 5, 1930. Earlier records cited, Miocene to Recent. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 290, pl. 14, figs. 2, 5, 10, 1931. Also cited from Oligocene to Recent. — Hertlein and Strong, Zoologica, Vol. 31, Pt. 3, p. 113, 1946. Gulf of California, Recent. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press), p. 94, fig. 188, 1958. Catalina Island, California, to Mazatlan, Mexico, in 16 to 66 fathoms. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 208, pl. 29, figs. 7, 7a, 1961.

Type specimen. — British Museum (Natural History) (Keen, 1968).

Type locality. — "Mazatlan." [Mexico.]

Range. — Late Oligocene (Wagner and Schilling) (701) to Recent. Recent from San Pedro, California, to Mazatlan, Mexico, in 27 to 121 meters (15 to 66 fathoms).

Occurrence in San Diego Fm. — L.A.M. 107, 305, 305A, 319. S.D. 70.

Original description. — L. t. albâ, tenui, complanatâ; suborbiculari; striis concentricis exillimis; postice angulatâ, umbonibus incurvatis; lunulâ parvâ, alte excavatâ, dent. card et. lat. haud magnis; impressionibus muscularibus posticâ ovali, anticâ valde elongatâ; margine integro. (Carpenter.)

Distinguished by the very small, most deeply cut lunule, bounded on one side by the cardinal, on the other by the anterior lateral tooth. A larger lunular portion is marked out by a line, and the posterior margin is slightly bi-angulated. Smallest valve 0.03 across. Largest, long. 0.38, lat. 0.41, alt. .12. (Carpenter.)

Remarks. — About 75 valves of this species from the San Diego Formation, varying in size from 6.4 to 19.3 mm in length, have been available for study. Most of these are in the collections of the Los Angeles County Museum from near the Mexican boundary but a few are from San Diego. A right valve, 12.4 mm long, in the collections of the San Diego Society of Natural History, was collected by Samuel Harter in Balboa Park.

The globosity of the various valves varies as does the spacing of the ribbing which may be closely or widely separated.

Through the courtesy of Dr. Horace G. Richards, Academy of Natural Sciences of Philadelphia, we have been able to examine casts of Gabb's type of *Lucina richthofeni.* We have not observed any essential differences between these and Recent specimens of *L. excavata* from the Gulf of California. We have, albeit regretfully, placed Gabb's species from the Pliocene in the synonymy of the Recent form.

Lamy (702) first stated that *Lucina excavata* represented the young form of *L. richthofeni* Gabb and later, Stewart, who studied Gabb's type specimens, placed *L. richthofeni* in the synonymy of Carpenter's species. Both Lamy and Stewart, pointed out that *Lucina "excavata?"* cited by d'Orbigny (703) in 1850 was based upon *Cytherea excavata* Morton (704) from the Cretaceous of New Jersey, which species is the type of *Cyprimeria* Conrad. It is not referable to the genus *Lucina* and does not affect the nomenclature of *L. excavata* Carpenter.

A subspecies, *Lucina (Here) excavata temblorensis* Adegoke (705), of middle Miocene age, was described from the Coalinga district. It is said to differ from the typical subspecies in the more prominent beaks, less circular outline and in other features.

SUBGENUS *LUCINISCA* DALL

Lucinisca Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, p. 805, August 22, 1901. "Type, *Lucina nassula* Conrad." — Chavan, Jour. de Conchyl., Vol. 81, No. 4, p. 238, 1937. Genotype: *L. nassula* Conrad.

Type species (by original designation). — *Lucina nassula* Conrad [Proc. Acad. Nat. Sci. Philadelphia, Vol. 3, p. 24, 1846. "Tampa Bay, Florida." Recent. Illustrated by Conrad, Amer. Jour. Conch., Vol. 2, Pt. 3, p. 281, pl. 15, fig. 7, 1866 (as *Lucina lintea).* "Inhabits Tampa Bay, Florida." — Perry and Schwengel, Marine Shells of the western coast of Florida (Paleo. Res. Inst.: Ithaca, New York), p. 64, pl. 11, fig. 65, 1955.]

Range. — Early Miocene to Recent. Recent in warm temperate and tropical marine waters, from the intertidal zone to 183 meters (100 fathoms).

Original description. — Shell lentiform, white, with well-marked dorsal areas, the sculpture reticulate and muricate, the right anterior cardinal obsolete. (Dall.)

Remarks. — The shells of the subgenus *Lucinisca* are characterized by their scaly reticulate sculpture, only slightly asymmetric lunule and by their denticulate inner margins. Chavan (706) published illustrations of the hinge of *Lucina cribraria* Say, a member of this subgenus.

The members of this subgenus are almost entirely confined to the eastern and western coasts of the Americas where they are known to occur from early Miocene to Recent. Three species referred to *Lucinisca* have been reported from strata of Miocene age in Japan.

Three species and one subspecies of *Lucinisca* occur in west American marine waters between Santa Barbara, California (Lat. 34°23'N.), and Tumbez, Peru. During late Pleistocene time one of these ranged north to Tomales

Bay, California (Lat. 38°18 N.).

Key to Species and Subspecies of *Lucinisca*

A. Concentric ribs closely spaced . . . . *nuttalli*

B. Concentric ribs widely spaced . . . . . (subspecies) *antecedens*

Lucina (Lucinisca) nuttalli Conrad
Plate 45, Figures 1-4; Plate 46, Figure 21

L[ucina]. nuttalli Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 255, pl. 20, fig. 2, 1837. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 62, "Pacific Beach;" p. 133, "Pliocene. — San Diego (Arnold)," 1903. — Arnold, U. S. G. S., Prof. Paper 47, p. 28, 1906. "Pacific Beach, north of San Diego, San Diego County." — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) cited.

Lucina nuttallii Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "well at San Diego," "Pliocene." — Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 27, 28, 1878. P. 11, Later Tertiary of San Diego; p. 27, lower bed (A), San Diego Peninsula; p. 28, San Diego well. — Orcutt, West. Amer. Sci., Vol. 6, Whole No. 45, p. 70, Pacific Beach, Tertiary; Whole No. 46, p. 85, Dall's record (1874) cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited.

Phacoides nuttallii Conrad, Gardner, Jour. Entom. Zool., Vol. 9, No. 3, p. 107, pl. 1, fig. 16, 1917. Laguna Beach, California, Recent. — Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 126, 1924. "Pliocene at San Diego." Also other localities. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 84, 1929 (as *Phacoides nuttalli*). "San Diego Pliocene." — Johnson and Snook, Seashore Animals of the Pacific Coast (Macmillan Co.: New York), ed. 1935, p. 438, fig. 414.

Lucina (Myrtea) nuttallii Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 288, pl. 14, figs. 4a, and 4b (Recent), fig. 18 (Pliocene east of Fernando Pass, Los Angeles Co., 1931. "Pliocene of Pacific Beach, San Diego (Arnold, 1903)."

Lucina (Lucinisca) nuttalli Conrad, Hertlein and Strong, Zoologica, Vol. 31, Pt. 3, p. 114, 1946. Santa Barbara California, to Manzanillo and the Tres Marias Islands, Mexico. Also late Miocene to Recent. — Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 76, pl. 18, figs. 4, 5, 1950. Upper Pliocene to Recent. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 96, fig. 191, 1958. Southern California to the Tres Marias Islands, Mexico.

Lucinisca nuttalli Conrad, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 40, pl. 18, fig. d, 1968. Balboa Park, San Diego, Pliocene.

Type specimen. — Two syntypes, 61.5.20.87, British Museum (Natural History) (A. M. Keen, Veliger, Vol. 8, No. 3, p. 169, 1966).

Type locality: "Inhabits California with the above" [that is, *Lucina californica* and *L. bella* which "Inhabits muddy marshes near Sta. Diego; common."]

Range. — "cf." Early Miocene (Vaqueros; Temblor). Late Miocene to Recent. Recent from Santa Barbara, California, to Punta Peñasco and San Felipe in the Gulf of California and south to Manzanillo, and the Tres Marias Islands, Mexico; littoral zone to 46 meters (25 fathoms).

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 957, 1129, 1178, 1400, 1401, 1402, 1415, 28880, 28885, 28886, 28892. L.A.M. 104, 107, 302, 305, 305A, 318, 319, 323. S.D. 21, 29, 38, 79, 80, 331, 365, 408. U.C.L.A. 294, 302, 312, 331, 1386, 2359.

Original description. — Shell lenticular, slightly compressed; disks cancellated; concentric lines very regular, lamelliform, prominent; anterior fold small, marginal; extremity emarginate above; cardinal and lateral teeth distinct; inner margin minutely crenulated. (Conrad.)

Remarks. — Over 100 valves of this species from the San Diego Formation have been available for study. Most of these are in the collections of the Los Angeles County Museum from near the Mexican boundary and others from San Diego. One of the largest valves from Loc. 305 (LAM), is 25.9 mm. long, 25 mm high and the convexity 7.7 mm.

This species occurs fairly commonly in the San Diego Formation. The scaly, reticulate sculpture and denticulate inner margins are features which serve to separate this species and its subspecies from others of *Lucina* which occur in strata of Pliocene age in San Diego.

Variation in the degree of rounding of the outline and in the convexity was observed in a series of specimens of *L. nuttalli.* Durham (707) mentioned specimens from beds of late Pliocene age in the Gulf of California region which were more tumid than usual for this species, but he acknowledged that occasional Recent specimens are nearly as convex.

Specimens cited as "*Phacoides (Lucinisca)* cf. *nuttallii*" (708) have been recorded from beds of early Miocene age in southern California and the species is well known in Pliocene and Pleistocene beds in southern California and in Lower California.

A subspecies, *Lucina nuttallii antecedens* Arnold, was described from strata of Pliocene age in Santa Barbara Co., California. *Lucina nuttalli centrifuga* Dall (709), described as a variety from the Gulf of California, has the concentric lamellae near the beaks widely spaced, more elevated and fringed with flat spinules. Some specimens identified as this subspecies from the Gulf of California which we have observed are very similar to young specimens of the species later described as *Lucina liana* Pilsbry (710).

Fossils from Miocene strata in Japan have been recorded in the literature by Nomura (711) under the name of *Lucina nuttalli* and another species *Lucina yokoyamai* Otuka (712), also from Miocene beds, is said to bear some resemblance to Conrad's species. We have not seen specimens but evidently *L. nuttalli* or a very similar form was present in Japan during Miocene time.

At the present time, *Lucina nuttalli* has been recorded

as ranging north to Santa Barbara, California, but during late Pleistocene it ranged north to Tomales Bay, California. We have examined specimens from the Tres Marias Islands, Mexico, which are typical *L. nuttalli.*

Lucina (Lucinisca) nuttalli antecedens Arnold
Plate 46, Figures 8, 9, 13, 14

Phacoides nuttalli Conrad, var. *antecedens* Arnold, Smithsonian Misc. Coll. (Quarterly Issue), Vol. 50, Pt. 4, p. 436 (separate p. 18), pl. 55, fig. 6, December 13, 1907.
Lucinisca nuttallii antecedens Arnold, Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 207, pl. 86, pl. 20, fig. 3; pl. 21, fig. 6, 1950. Diatomaceous strata of Sisquoc Formation; Foxen Mudstone; Careaga Sandstone, late Pliocene.

Type specimen. — No. 165290, United States National Museum.

Type locality. — "Alcatraz asphalt mine, near Sisquoc, Santa Barbara County, California; locality No. 4471." "Fernando formation, lower Pliocene portion."

Range. — Middle and late Pliocene.

Occurrence in San Diego Fm. — L.A.M. 107, 124, 305.

Original description. — Shell averaging about 25 millimeters in longitude, very broadly elliptical in outline, longer than high, ventricose, and equivalve; beaks only moderately prominent, placed slightly anterior to middle of shell; base arcuate; anterior margin sloping more rapidly from beaks than posterior, the latter being nearly straight for about 6 or 8 millimeters from the beaks; both extremities quite regularly rounded, the posterior being possibly slightly more attenuate, sculpture consisting of numerous close-set subequal rounded radiating ridges and concentric ribs which are narrower than the radials, and spaced about twice the distance between two of the latter; the concentric ribs tend to become obsolete toward the periphery in adult specimens; the general appearance of the surface is decidedly cancellate. Lunule deep, small, and inconspicuous. Interior and hinge as in *P. nuttallii.* (Arnold.)

Dimensions. — Longitude, 23 mm; altitude 19 mm; diameter, 12 mm. (Arnold).

Remarks. — A few valves in the collection from Loc. 305 (LAM), are here referred to *Lucina nuttalli antecedens.* The largest one is 18 mm long, 17.3 mm high and 4.5 mm in convexity. These specimens are rather rounded and the concentric lamellae on the major portion of the shell below the umbonal area, are widely spaced. These fossils are similar to others from the type locality of *L. n. antecedens.*

Arnold mentioned the diagnostic characters of this form as follows: "This variety is more ventricose, less angulated posteriorly, and its concentric ribs much wider spaced than the typical *nuttallii.*" Woodring (1950) mentioned that the lamellae in the early stages on this subspecies are closely spaced but are succeeded by more widely spaced lamellae, which in later stages may be irregularly spaced.

The specimens here illustrated were selected from among an assemblage of a large number of individuals of *L. nuttalli* and it appears to us that the present subspecies is of doubtful value as a taxonomic unit. However, the presence of these specimens in the San Diego Formation, which reveal a tendency to develop the characters mentioned by Arnold has led us to identify them with *L. n. antecedens.*

A cast, highly convex, from Reynard Way in San Diego and perhaps a few valves from Loc. 124 (LAM) are doubtfully referred to the form named by Arnold.

Woodring, 1950, recognized only *L. n. antecedens* in Pliocene strata at its type locality and in adjacent areas in Santa Barbara Co.

SUBGENUS *LUCINOMA* DALL

Lucinoma Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, p. 806, August 22, 1901. "Type, *Lucina filosa* Stimpson." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1362, October, 1903. Type, *Lucina filosa* Stimpson. — Chavan, Jour. de Conchyl., Vol. 82, No. 1, p. 80, 1938. Genotype, *Lucina filosa* Stimpson.

Type species (by original designation). — *Lucina filosa* Stimpson. [*Lucina filosa* Stimpson, Shells of New England, p. 17, 1851. Illustrated by Stearns, Proc. U. S. Nat. Mus., Vol. 13, No. 813, p. 220 (in text), pl. 17, figs. 5, 6, 1890. — Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, pp. 809, 824, pl. 40, fig. 11, 1901 (as *Phacoides (Lucinoma) filosus*). See also illustrations of hinge of *L. borealis* Linnaeus by Lamy, Jour. de Conchyl., Vol. 65, No. 2, p. 171, 1920.]

Range. — Late Oligocene to Recent, widespread. Recent species in western North America live in marine waters between Afognak Island, Alaska, and the Gulf of California, at depths of 15 to 1838 meters (8 to 1005 fathoms).

Original description. — Shell usually large, lentiform, white, with a conspicuous periostracum, concentrically lamellose or striated; the cardinal teeth developed, the inner pair usually bifid; the laterals obsolete or absent, the inner margins entire. (Dall.)

Remarks. — This group of lucinids with well developed concentric lamellar sculpture and weak lateral teeth is widely distributed geographically and geologically. Five and perhaps six species referable to *Lucinoma* have been described from late Oligocene to Recent, in western North America, and one of these, a Recent species, occurs in the San Diego Formation. Three Recent species live in west American waters.

Lucinoma also is represented in the late Cenozoic of eastern North America, South America, Europe, Japan, and New Zealand. It is well represented in the north Pacific. Hirayama (713) discussed several species of Miocene age occurring in Japan. Far to the southwest, Powell described *Myrtea (Lucinoma) taylori* (714) from beds of Awamoan, early Miocene age, in New Zealand. Dell (715) described a Recent species, *Lucinoma marwicki,* from a depth of 361 meters in the same region, and more recently Lemche added *Lucinoma galatheae* (716) to the known molluscan fauna of New Zealand.

In general, as pointed out by Dall, the members of *Lucinoma* prefer cool water. However, species also are known to occur in tropical waters. *Lucina (Lucinoma) chiripanica* Olsson (717) was described from beds of Pliocene age in Panama. Melville and Standen (718) recorded a tropical variety of *Lucina borealis* in the Persian Gulf and Thiele and Jaeckel (719) cited the same species from the East Indies, and there are other examples.

Alucinoma Habe (720) differs from *Lucinoma* in lacking cardinal teeth.

Lucina (Lucinoma) annulata Reeve
Plate 46, Figures 12, 19

Lucina annulata Reeve, Conch. Icon., Vol. 6, *Lucina*, sp. 17, pl. 4, fig. 17, May, 1850.

Lucina borealis Linnaeus, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "Well at San Diego," "Pliocene." — Cooper, Calif. State Min. Bur. Seventh Ann. Rept. State Mineral., p. 246, 1888. "San Diego Well." — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, 1889. Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) cited and referred to *Lucina (Lucinoma) annulata.*

Not *Lucina borealis* Linnaeus, 1767. "In Oceano Europaeo."

Lucina acutilineata Conrad, Dall, Proc. U. S. Nat. Mus., Vol. 1, pp. 11, 28, 1878. P. 11, Later Tertiary of San Diego; p. 28, San Diego well. — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 86, 1889. Dall's record (1878) cited. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 132, 1903. "San Diego well (Cooper)." — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1878) cited.

Not *Lucina acutilineata* Conrad, 1848.

Phacoides acutilineatus Conrad, Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 179, 1909. "San Diego well (Cooper)."

Phacoides annulatus Reeve, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 174, 182, 1912. "San Diego-Purisima," Pliocene. — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 263, pl. 19, figs. 5a, 5b, 1918. "Range. — Alaska to Coronado Island, California (Dall)."

Phacoides (Lucinoma) annulatus Reeve, I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 38, pl. 37, figs. 5a, 5b, 1924. "Port Althorp, Alaska, to Coronado Islands, Lower California." Recent. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 126, pl. 33, figs. 5a, 5b, 1924. Same range as in preceding reference. Also, late Miocene, Pliocene, Pleistocene. — Abbott, American Seashells (D. Van Nostrand Co., Inc.: New York), p. 389, fig. 28f (p. 83), 1954. Alaska to southern California, in 8 to 75 fathoms.

Lucina (Myrtea) acutilineata Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 287, pl. 14, figs. 22a, 22b (Pleistocene of San Pedro), 1931. "San Diego well, middle Pliocene, San Diego (Cooper)."

Not *Lucina acutilineata* Conrad, 1849.

Lucinoma annulata Reeve, Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 97, fig. 197, 1958. Gulf of California. — Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 40, pl. 18, figs. a, b, c, 1968. Balboa Park, San Diego, Pliocene.

Type specimen. — Syntypes Nos. 1963 121/1-2, British Museum (Natural History).

Type locality. — "Hab. California?"

Range. — Late Miocene to Recent. Recent from Afognak Island (Kodiak group), and Macleod Bay, Montague Island, Alaska, to Santa Inez Bay, Lower California; in 18 to 757 meters (10 to 414 fathoms) (Woodring, U. S. G. S., Prof. Paper 190, p. 53, 1938). Japan.

SUBGENUS *EPILUCINA* DALL

Epilucina Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, p. 806, August 22, 1901. "Type, *Lucina californica* Conrad." — Chavan, Jour. de Conchyl., Vol. 81, No. 4, pp. 249, 272, 1937. Genotype, *Lucina californica* Conrad.

Type species (by original designation). — *Lucina californica* Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, p. 255, pl. 20, fig. 1, 1837. Near San Diego, California. Hinge illustrated by Chavan, 1937, p. 274, fig. 10.

Range. — Bathonian, late Jurassic, to Recent (Chavan). Recent from the intertidal zone to 143 meters (78 fathoms).

Original description. — Shell veneriform, convex, all the hinge teeth developed, inner margins entire; otherwise like *Callucina.* (Dall.)

Remarks. — The shell of *Epilucina*, as pointed out by Chavan, differs in several important details from that of *Callucina* Dall (729) which has as its type *Lucina radians* Conrad. Among those differences are, the position of the lunule which is situated entirely in the right valve instead of partly in the left one, smooth inner margins and strongly projecting laterals (which on *Callucina* are very slightly developed).

We have not studied species upon which Chavan based the early range of this subgenus. *Claibornites* Stewart, 1930, was relegated to the synonymy of *Epilucina* by Chavan.

Lucina (Epilucina) californica Conrad
Plate 46, Figures 11, 16

L[ucina]. californica Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 255, pl. 20, fig. 1, 1837.

Phacoides californicus Conrad, Keep, West Coast Shells (The Whitaker & Ray-Wiggin Co.: San Francisco, Calif.), p. 67, fig. 43, 1911. "coast of central California". Also ed. by Baily, 1935, p. 82, fig. 55. — Johnson and Snook, Seashore Animals Pacific Coast (Macmillan Co.: New York), p. 438, fig. 415, 1935.

Lucina (Myrtea) californica Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 285, pl. 14, figs. 15a, 15b, 21a, 1931. Pliocene to Recent.

Codakia californica Conrad, Abbott, American Seashells (D. Van Nostrand Co., Inc.: New York, London; Toronto), p. 390, pl. 31, fig. c, 1954. "Crescent City, California, to Lower California."

Type specimen. — Location unknown to the present authors.

Type locality. — "Inhabits the coast of California with the above, but rare." [Preceding species is *Lucina bella* from "Inhabits muddy marshes near Sta. Diego; common."]

Range. —?Late Miocene; middle Pliocene to Recent. Recent from Crescent City, California, to San Ignacio Lagoon, Lower California, from the intertidal zone to 143 meters (0 to 78 fathoms). Reported from Alkai Point, Seattle, Washington, by Eyerdam (730).

Occurrence in San Diego Fm. — L.A.M. 305, 305A, 318. S.D. 5. U.C.L.A. 294, 295.

Original description. — Shell lenticular, with coarse concentric striae; posterior extremity direct; lunule small, elliptical, impressed, transversely striated, prominent in the right valve, and fitting into a corresponding depression in the left; cardinal and lateral teeth prominent. (Conrad.)

The lunule in the shell is remarkable for forming a distinct tooth, and the shell is destitute of a fold. (Conrad.)

Remarks. — Several valves of this species are in the collections from near the Mexican boundary. Small valves up to 9 mm in length are very elongated. The largest valve from Loc. 305 (LAM) is 19.5 mm long. Two small right valves from the south slope of Mount Soledad, are in the collection of the San Diego Society of Natural History. The larger one is 13.6 mm long, 13.7 mm high, convexity, 4.2 mm. A large Recent specimen collected at San Diego by Henry Hemphill is 35.9 mm long, 34 mm high, the convexity (both valves together), 19 mm. The hinge of this species has been illustrated by Chavan (731).

The shell of this species is easily separable from that of other species of *Lucina* occurring in Pliocene beds in California by the complete lack of any depressed area either posteriorly or anteriorly, concentric sculpture only, and in the character of the lunule which lies entirely in the right valve.

The species described as *Lucina (Myrtea) nipponica* Nomura and Hatai (732) from beds of middle Miocene age in Japan was compared with *L. californica.* The Japanese species was said to differ in the smaller size, finer sculpture, and in the somewhat different outline.

Lucina californica is known to occur in beds of late Pliocene age on Cedros Island, Lower California, from Fourth and Broadway streets in Los Angeles, and the present record adds its occurrence in the San Diego Formation. Gale (733) recorded it with question in the lower zone in the Frutivale district in the San Joaquin Valley in strata of late Miocene age. However, Grant and Gale in their later work (1931) made no mention of this record. It occurs commonly in Pleistocene deposits in southern California and northern Lower California as well as Recent.

SUBGENUS *PARVILUCINA* DALL

Parvilucina Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, p. 906, August 22, 1901. "Type, *Lucina tenuisculpta* Carpenter." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1362, 1903. Type, *Lucina tenuisculpta* Carpenter. — Woodring, Carnegie Inst. Washington, Publ. 366, p. 125, 1925. Type as designated by Dall. — Chavan, Jour. de Conchyl., Vol. 81, No. 3, p. 208, 1937. Genotype, *Lucina tenuisculpta* Carpenter.

Type species (by original designation). — *Lucina tenuisculpta* Carpenter [Rept. Brit. Assoc. Adv. Sci., for 1863, p. 642, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 128, 1872. Cited from "Puget's Sound and the neighbourhood" and the region between San Diego and San Pedro, also the Santa Barbara Islands. "4 fm. living, Cp." The island variety, 120 fms. Illustrated by Dall, 1901, p. 828, pl. 40, fig. 5, 1901. — Chavan, 1937, p. 209, fig. 4. — K. V. W. Palmer, Geol. Soc. Amer. Mem. 76, p. 86, pl. 8, figs. 8-12, 1958. (Holotype).]

Range. — Late Cretaceous (Senonian) (Chavan, Treatise on Invert. Paleo., Pt. N, Moll. 6, Bivalvia, Vol. 2, p. N498, 1969); mid-Eocene to Recent, North America (Woodring). Recent from the intertidal zone to 525 meters (287 fathoms).

Original description. — Shell small, plump, often inequilateral; sculpture more or less reticulate but not muricate, teeth small, but all usually present. For *Parvilucina s. s.*: Dorsal areas obscure or obsolete, sculpture feeble. (Dall.)

Remarks. — This subgenus is represented in the late Cenozoic of western North America by two species and a subspecies, the latter occurs in the San Diego Formation.

A subgenus *Callucinella* Chavan (734) was described as differing from *Parvilucina* in the larger size, irregular concentric sculpture, very fine crenulations on the margin, and longer lunule. The hinge also differs from *Parvilucina*, among other features, in the presence of a lateral lamella and in the elongated cardinal teeth, especially the posterior ones.

Lucina (Parvilucina) tenuisculpta intensa Dall
Plate 46, Figures 6, 7, 17, 22

Lucina tenuisculpta Carpenter, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. Well at San Diego, California, Pliocene. — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. From "well-digging in stratum B^2", San Diego, Pliocene. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 48, 1944. Dall's record (1874) cited.

Not *Lucina tenuisculpta* Carpenter.

Phacoides (Parvilucina) intensus Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1385, pl. 50, fig. 8, October, 1903. — Schuchert, Dall, et al., U. S. Nat. Mus., Bull. No. 53, Pt. 1, p. 497, 1905. Original locality cited. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 98, 1944. Original locality record cited.

Phacoides intensus Dall, Arnold, Smithsonian Misc. Coll. (Quart. issue), Vol. 50, Pt. 4, pp. 423, 445, pl. 56, figs. 9a, 9b, 1907. One mile north of Schumann; "Waldorf asphalt mine". "Found in lower Pliocene as far south as San Diego." — Arnold, U. S. G. S., Bull. 322, pp. 59, 148, pl. 23, figs. 9a, 9b, 1907. [Same locality information as in preceding reference.] — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 288, 1931. [In synon. of *Lucina (Myrtea) tenuisculpta* Carpenter]. Dall's record (1874) cited. — Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, p. 86, 1950. "Pliocene strata encountered in a well at San Diego."

Type specimen. — No. 135041, United States National Museum.

Type locality. — "Pliocene of San Diego, California, from a depth of one hundred and sixty feet below the surface in the city park well; Hemphill."

Range. — Middle and late Pliocene in southern California.

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 305, 305A, 318, 319. U.C.L.A. 294.

Original description. — Shell small, resembling *P. tenuisculptus* Cpr., but with the concentric sculpture

much sharper though very fine, the radials feeble, the lunule large, lanceolate, and impressed, the beaks small and prominent, the hinge very delicate, the posterior dorsal area with a wide, shallow sulcus, and the inner margins rather coarsely crenulate. Alt. 4.5 mm, long. 5.0 mm, diam. 3.0 mm. (Dall, 1903.)

Remarks. — Five valves from the original lot collected by Henry Hemphill from which the type of this species was described are in the type collection in the Department of Geology of the California Academy of Sciences. The largest, a left valve, is approximately 8 mm long, 6.4 mm high, convexity, 3.4 mm. The other valves in the collection are much smaller.

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 957, 1135, 1178, 1181, 1182, 1183, 1186, 1399, 1400, 1401, 1402, 1413, 1415, 1418, 1419, 12053. L.A.M. 104, 107, 122, 305, 305A, 319, A-1323. S.D. 34, 38, 79, 150, 331, 365, 2930. U.C.L.A. 294, 295, 2359.

Original description. — Shell orbicular, rather flattened, inequilateral, concentrically laminately ridged, ridges sharp, erect, interstices concentrically striated, lunule lanceolately ovate, rather deeply excavated; semi-transparent white. (Reeve.)

Remarks. — This species is encountered rather commonly in the San Diego Formation. It is easily recognized by its rounded form, nearly straight posterior dorsal margin and well developed and well spaced (about 2.5 to 3 mm apart) concentric lamellar sculpture.

We have observed about 30 valves and a number of casts of this species from the San Diego Formation. The largest valve, from Loc. 305 (LAM), is 61.6 mm long and 57 mm high. Young specimens have a weak anterior lateral tooth.

Some writers have considered this species to be identical with *Lucina acutilineata* Conrad (721) which was originally described from beds of Miocene age at Astoria, Oregon. The length was given as 1 1/2 inches, the height slightly less than the length and the "thickness 45/100 L." Stewart (722) examined Conrad's type specimen and stated that it has a shorter posterior dorsal margin than that of Recent *L. annulata.* Woodring (723) also recognized this difference between the two, mentioned that Miocene specimens are usually smaller than Recent shells and designated a specimen as lectotype of *L. acutilineata.* A Recent specimen of *L. annulata* from Loc. 34051 (CAS), dredged in 165 meters (90 fathoms) off Gaviota, California, is 73 mm long and 66 mm high.

Dall's (724) diagnosis of "*Phacoides acutilineatus*" was based upon a somewhat worn specimen of Pliocene age from Coos Bay, Oregon, and may not be referable to Conrad's species.

The generally longer posterior dorsal margin, much greater size, and hinge characters of the Pliocene and Recent shells, justify assigning them to *Lucina annulata* with the status of a distinct species.

Lucina annulata desilirata Dall (725) was described as differing from the typical form in the more steeply sloping posterior dorsal margin and in that the primary concentric lamellae are more irregularly spaced.

The species described as *Phacoides columbianum* Clark and Arnold (726), closely resembles *L. acutilineata* but it was said to differ in lacking a posterior depressed area and in possessing an anterior lateral tooth on the hinge of the left valve.

Lucina hannibali Clark (727), which occurs commonly in the Blakely Formation of Washington and in beds of equivalent age in Alaska and Japan, is characterized by the attenuated anterior portion of the shell.

Two Recent species occurring in west American waters, *Lucina aequizonata* Stearns and *L. heroicus* Dall, have more steeply sloping dorsal margins and thus differ in outline from *L. annulata.*

Lucina annulata has been recorded (728) occurring in Japanese waters from 31° to 41°North latitude and several similar species occur as fossils in strata of late Tertiary age in the same region.

Over a hundred and fifty valves are in the collections of the Los Angeles County Museum from near the Mexican boundary. The largest one, from Loc. 319 (LAM), is 8 mm long.

These valves differ from Recent specimens of *Lucina (Parvilucina) tenuisculpta* Carpenter (735) chiefly in their smaller size, stronger concentric sculpture and in the larger lunule. Large specimens of *L. tenuisculpta* from Port Orchard, Puget Sound, are 11 mm long and 10 mm high; and Woodring mentioned specimens of this species which are 14 mm long.

Woodring believed that the apparent stronger concentric sculpture of *Lucina intensa* mentioned by Dall in comparison with Carpenter's species may be due to erosion of the early portions of Recent shells of *L. tenuisculpta.* The consistently smaller size of the Pliocene fossils together with the larger lunule, and at least in the type series, stronger concentric sculpture leads us, at least for the present, to assign subspecific status to the form described by Dall.

Lucina (Parvilucina) approximata Dall (736) described from the Gulf of California bears some similarity to *L. tenuisculpta intensa,* but it has much stronger radial sculpture.

GENUS *MILTHA* H. AND A. ADAMS

Miltha H. and A. Adams, Gen Rec. Moll., Vol. 2, p. 468, April 1857. Sole species, *Lucina (Miltha) childreni* Gray. — Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 88, November, 1953. Type by monotypy. — Vokes, Tulane Studies Geol. Paleo., Vol. 7, No. 3, p. 95, December 29, 1969. Type by monotypy.

Type species (by monotypy). — *Lucina (Miltha) childreni* Gray [=*Lucina childrinae* Gray, Zool. Jour., Vol. 1, No. 2, p. 221, footnote, June, 1824. No locality cited. (In errata, "for *childrinae*, read *childreni.*") — Gray, Ann. Philos., New Ser., Vol. 9, p. 136, February, 1825 (as *Lucina childrenae*). "Brazile". — Reeve, Conch. Icon., Vol. 6, *Lucina*, sp. 12, pl. 3, fig. 12, 1850 (as *Lucina childreni*). "Brazile." — Wilkins, Bull. Brit. Mus. (Nat. Hist.), Historical Ser., Vol. 1, No. 4, p. 159, pl. 23, fig. 6, March, 1957. "From Brazil." "Lectotype." — Vokes, 1969, p. 116, pl. 1, fig. 1; pl. 2, figs. 1a, b; pl. 4, figs. 1-4 (as *Miltha (Miltha) childrenae*).

Range. — Eocene to Recent. East and west coasts of the Americas (*Miltha, s. s.*). Recent from 33 to 101 meters (18 to 55 fathoms). Also reported from the late

Tertiary of Australia and New Zealand.

Description. — Shell subovate to subelliptical with a fine to coarse concentric sculpture. Lunule asymmetrical, larger in the left valve and generally transgressing across the valve margin into the interior. Ligament large, external, immersed. Anterior adductor scar very long and narrow, near or quite widely separated from the pallial line which is parallels. (Olsson and Harbison.)

The hinge of *Miltha* has two teeth in each valve but laterals are lacking.

Remarks. — The large suborbicular, depressed inequivalve lucinids referred to *Miltha s. s.* appear to be limited to the American region during both past and present time.

Several groups of species formerly cited under *Miltha* have been placed under separate subgenera. *Pseudomiltha* Fischer (737), an Eocene-Oligocene group has a virtually edentulous hinge. *Eomiltha* Cossman (738), Eocene to Recent, differs from *Miltha* in that it is more produced anteriorly, the pallial line is close to the margin, the anterior adductor impression is narrower, longer, and farther from the pallial line and the hinge lacks anterior lateral-like ridges. *Plastomiltha* Stewart (739) is said to differ from *Miltha* in the deeper lunule, smaller cardinal teeth, and in that the anterior adductor impression is narrower. Olsson and Harbison (1953, pp. 83-84) consider that subgenus to be confined to beds of Eocene age and they consider it to be more closely related to "*Phacoides*" than to *Miltha*. *Armimiltha* Olsson and Harbison (740) based upon *Lucina disciformis* Heilprin, a Pliocene species, is said to differ from *Miltha* in the much stronger sculpture and from *Plastomiltha* by the larger lunule which with growth partially effaces the cardinal teeth, the larger of which is double.

Species of *Miltha s. s.* inhabit tropical or subtropical waters at the present time and apparently this also was true of the fossil forms of this group. Species referred to this and related subgenera (or genera) lived in widely separated regions of the world during later Tertiary time. Species have been described from California and Lower California, Peru, Argentina, Florida, and New Zealand. The distribution of *Miltha* in the later Tertiary of southeastern Australia was discussed by Wilkins (741). A recent paper by Vokes (742) contains a comprehensive account of the genus *Miltha* and of the Neogene species in Florida.

During early Miocene time in western North America *Miltha s. s.* ranged as far north as Santa Cruz Co., California. During Pliocene time it occurred as far north as San Benito Co., whereas during succeeding Pleistocene time it is known with certainty to occur only as far north as Magdalena Bay on the west coast of Lower California.

Khomenko (743) recorded a species assigned to this genus from beds of the Matchgar section, middle Miocene, in the Schmidt Peninsula, Kamtschatka, but we have not seen specimens from that region.

Recent species of *Miltha s. s.* now live only in waters of Brazil and the Gulf of California.

SUBGENUS *MILTHA* S. S.

Miltha (Miltha) xantusi Dall
Plate 45, Figures 14-17

Phacoides (Miltha) childreni Gray, Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, p. 812, 1901. "Gulf of California, Cape St. Lucas, Mazatlan."

Not *Lucina childrinae* Gray, 1824. (*Lucina childrenae* Gray, 1824).

Phacoides (Miltha) xantusi Dall, Nautilus, Vol. 18, No. 10, p. 111, February 1905. "Cape St. Lucas."

Phacoides sanctaecrucis Arnold, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 167, 174, 1912. "San Diego-Purisima." Pliocene.

Not *Phacoides (Miltha) sanctaecrucis* Arnold, 1909 (1910).

Phacoides xantusi Dall, Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, pp. 84, 85, 1929. "San Diego Pliocene."

Lucina (Miltha) xantusi Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 291, pl. 14, figs. 20a, 20b (middle Pliocene of Holser Canyon, Los Angeles Co.), 1931. [Not all the synonymy.] — Hertlein and Strong, Zoologica, Vol. 31, Pt. 3, p. 115, pl. 1, fig. 13, 1946. Cape San Lucas, Lower California, Arena Bank, Gulf of California, Recent.

Miltha xantusi Dall, Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 77, pl. 19, figs. 3, 8, 1950. Coronado Island, Gulf of California, Pleistocene. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 215, pl. 30, fig. 4, 1961. Lower California. — Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 40, pl. 18, figs. e, f, 1968. Balboa Park, San Diego, Pliocene.

Miltha (Miltha) xantusi Dall, Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 98, fig. 198, 1958. Taken mostly off Cape San Lucas, Lower California, in 30 or more fathoms.

Type specimen. — No. 5383, United States National Museum.

Type locality. — "Cape St. Lucas," Lower California, Mexico.

Range. — Late Miocene (Castaic Formation)(744), to Recent. Recent, Cabo Haro, west of Guyamas Bay, Sonora, to Mazatlan, Sinaloa, and La Paz to Cape San Lucas, Lower California, Mexico, in 33 to 101 meters (18 to 55 fathoms).

Occurrence in San Diego Fm. — C.A.S. 1401, 1402. L.A.M. 302, 305, 305A, P.87. S.D. 29, 61, 80, 5251. U.C.L.A. 2359.

Original description. — "The *P. xantusi* seems to be a smaller species when adult, more rounded, more equivalved and with a shorter ligament. It has a more or less bifurcate and vermiculate radial sculpture, that of *P. childreni* being finer, more regular and more distinctly divided into fine continuous radial grooves and a microscopic minor sculpture between them.

"As in many other Lucinacea, directly under the beaks there is a small impressed area. In *P. xantusi* this in the right valve projects so as to fill an excavation in the other valve and is so much impressed as to make the beak appear sharper and more produced and to distinctly arcuate the two cardinal teeth. . . . . In the California species the lunule is very small and bent vertically downward so that in the closed valves it is excavated and not projecting and has a length of about 6 mm. It is almost wholly confined to the right valve." Measurements: height, 71 mm, width 65 mm. (Dall, 1905.)

Remarks. — A large series of specimens referable to the present species is represented in the collections from

Balboa Park and Mount Soledad. These agree in all observable details with a Recent specimen from the Gulf of California illustrated by Hertlein and Strong as well as with fossil specimens from Pleistocene beds in the Gulf of California region such as illustrated by Durham. One of the largest specimens is 72 mm high, 67 mm long, the convexity (both valves together), 26.4 mm. A more rounded specimen is 68.5 mm high, 69.6 mm long, convexity, 22.4 mm (both valves together). A specimen from Loc. P. 87 (LAM), Reynard Way, San Diego, is 63 mm long, 63 mm high, convexity, 21.5 mm.

There is considerable variation in shape and in the degree of convexity. Young shells are generally more rounded in outline. Many shells, especially large ones, are elongated from beak to base. The left valve is usually flatter than the right, but in some specimens the valves are of nearly equal convexity, and occasionally the left valve may be the more convex of the two. The lunule as described by Dall is mostly in the right valve, is impressed, and is about 6 mm in length. On some specimens a submedian slight depression or faint broad groove extends from the umbo to the base, but on others it is lacking. The right valve has two cardinal teeth, slightly grooved in large specimens, the left valve with a shorter anterior cardinal and a posterior cardinal (sometimes faintly grooved) and a long posterior nymph. The interior of the valves sometimes bears fine pits, in others the interior may be thickened in part with shell material. The margins are smooth. Externally the surface is sculptured with concentric lines of growth, occasionally with deeper grooves and often with faint radial lines visible, especially on the medial portion of the valves. Recent shells are pure white.

This species was cited in the earlier literature under the name of *Lucina* or *Miltha childreni* Gray, the type of the genus *Miltha*, which occurs in Brazil. Dall, in 1901, cited it from the Gulf of California under the name of *Phacoides (Miltha) childreni* Gray. In 1903 he cited it as occurring in beds of Pliocene age at San Juan in the Gulf of California. Two years later he described the Recent species in the Gulf of California as *Phacoides (Miltha) xantusi*, and the fossil form from San Juan was described as *Phacoides joannis* (745). According to Dall, this Pliocene form "resembles the Recent *P. xantusi* in having the folded lunule, only, in this case, the margin is more deeply infolded and the shell heavier, more elongate-oval, and about one-fourth smaller. It measures 55 mm in height by 51 mm in width; *P. xantusi*, 71 x 65 mm, and *P. childreni*, 86 x 77 mm."

We have examined a cast of the type of *Phacoides joannis*, a left valve. The impressed lunular area on this specimen may be slightly deeper than that on *M. xantusi*, and the interior of the shell appears to be nearly filled with shell material. However, in all other particulars it agrees with specimens of *M. xantusi* of the same size. We are inclined to consider *M. joannis* to be referable to the Recent species, *M. xantusi*.

Phacoides (Miltha) sanctaecrucis Arnold (746) was described from strata of early Miocene age in the "reef bed" in the Devil's Den district, Kern Co., California. Arnold mentioned that his species" "is characterized by its large size, circular outline, slight angulation dorsally, compressed disk, prominent lunule and dorsal areas, and finely concentrically striate but otherwise unsculptured surface." He stated that it is closely allied to the Recent species in the Gulf of California "but may be distinguished by its shorter lunule and relatively greater breadth."

We have examined a cast of the type specimen of Arnold's species. The valves are thick, nearly equal in convexity and decidedly circular in outline. There is variation in the series of specimens of this species from beds of Miocene age, but in general the valves appear to be thicker, more nearly equal in convexity and more circular in outline in comparison with Recent and fossil specimens of *Miltha xantusi*. We are inclined, at least for the present, therefore, to retain *M. sanctaecrucis* as a distinct species.

Stoliczka (747) mentioned that the Cretaceous species described by Pictet and Campiche as *Lucina sanctaecrucis* (748) "may belong to *Mysia* rather than to *Lucina*." Fortunately, the original assignment of Arnold's species to the genus *Phacoides* avoids invalidation as a homonym of the European species.

The resemblance of *Miltha pacifica* Olsson (749), described from strata of Miocene age in Peru, to *M. sanctaecrucis* Arnold was pointed out by Olsson. *Miltha s. s.* is also represented in Argentina by *M. inheringiana* Doello-Jurado (750) described from beds of the Entrerrienne Formation of probable Miocene age.

Miltha neozealanica Marshall and Murdoch (751), described from late Tertiary beds in New Zealand, was said to resemble closely *M. sanctaecrucis* Arnold. This New Zealand species was made the type of *Milthoidea* Marwick (752), but according to Chavan, and Ludbrook (753), Marwick's genus can be placed in the synonymy of *Miltha s. s.*

Probably most of the records of *Miltha sanctaecrucis* from beds of Pliocene age in southern California are referable to *M. xantusi*. However, some specimens (754) from Pliocene beds in Imperial Co. do resemble Arnold's species.

Miltha xantusi is known to occur in Pliocene and Pleistocene beds in the Gulf of California region and in Pleistocene beds at Magdalena Bay, Lower California, where it was recorded by E. K. Jordan (755). This species, under the name of *Miltha childreni*, was reported by J. P. Smith (756) as occurring in strata of late Pleistocene age at San Pedro, California, but later workers have not mentioned it from those beds.

FAMILY DIPLODONTIDAE DALL (757)

Shells of this family are generally small (length up to about 40 mm), suborbicular to subtrigonal, convex or depressed, thin, white. Surface smooth or sculptured with fine growth lines, often minutely punctate or coarsely granulose. Ligament external but sometimes becoming partly immersed below the margin and attached to a flattened nymphal plate. Hinge with two cardinal teeth in each valve, of which the left anterior and the right posterior tooth are typically double or bifid. Adductor scars subequal in size and connected by an entire pallial line which is often wide and ribbon-like. [Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst., Ithaca, New York), p. 199, 1961).] Cretaceous to Recent.

Remarks. — As mentioned by Olsson, the subequal muscle impressions (the anterior one longer and narrower)

and double cardinal teeth of the hinge, as well as anatomical characters, are features in which the Diplodontidae differ from the Lucinidae.

Chavan (758) recently discussed the classification of this family. The subgenera *Diplodonta s. s.* and *Felaniella* are each represented by one species in the San Diego Formation.

GENUS *DIPLODONTA* BRONN

Diplodonta Bronn, Italiens Tertiär-Gebilde und deren organische Einschlüsse (Heidelberg), pp. IX, 96, p. XII (as "*Diglodonta*" (typ. err.), 1831. [Concerning the date of issue of this work see Bowden and Heppel, Jour. Conch., Vol. 26, No. 2, p. 109, Note 4, 1966.] Species cited: "*D. lupinus* nob. (*Venus lupinus* Brocchi l.c.II.p. 553. Taff. XIV. fig. 8.)" and "*D trigonula* n. sp." — Gardner, U. S. G. S., Prof. Paper 199-A, p. 79, 1943. Type as designated by Herrmannsen. — Eames, Phil. Trans. Roy. Soc. London, Ser. B, No. 627, Vol. 235, p. 378, 1951. (With Synon.). "Type species: *Venus lupinus* Brocchi, (non Linné). . ." —Chavan, Bull. Inst. Roy. Sci. Nat. Belgique, Tome 38, No. 23, p. 8, 1962. Type as indicated by Herrmannsen, "*Venus lupinus* Brocchi, 1814, (p. 553) non Linné = *Tellina rotundata* Montague, 1803 (p. 77, pl. II, Fig. 3) = var. *aequilateralis* Ceruelli, 1909."

Type species (designated by Herrmannsen, Indic. Gen. Malacozoorum, Bd. 1, p. 392, 1846). — "Typus: *Venus lupinus* Broc." [*Venus lupinus* Brocchi, Conch. Foss. Subapennina, Vol. 2, p. 553, pl. 14, fig. 8, 1814. "Abita nell' Adriatico (Ren.). Fossile in Valle di Andonae nel Piacentino." Italy, Pliocene. Illustrated by Bronn, Lethaea Geognostica, Bd. 3, p. 391, atlas, pl. 37, figs. 18a, b, c, 1853-1856. — Woodward, Man. Moll., ed. 4 (reprint), p. 458, pl. 19, fig. 9, 1910. "Miocene, Turin." — Chavan, 1962, p. 8, fig. 3.]

Range. — Cretaceous to Recent. Recent, from the intertidal zone to 1360 meters (744 fathoms).

Description. — Shell equivalve, not gaping, subcircular, the beaks subcentral and not prominent. Lunule and escutcheon not defined. External surface smooth or incrementally sculptured. Ligament chiefly external, supported on marginal nymphs. Hinge of right valve armed with a simple anterior and a bifid posterior cardinal; hinge of left valve armed with a bifid anterior and a simple posterior cardinal, so that in the closed valves the two outer cardinals are simple, the two inner ones bifid. Laterals absent. Adductor impressions oval, the anterior longer and narrower than the posterior. Pallial line entire. Inner margins of valves smooth. (Gardner, 1943.)

Remarks. — Nine species of *Diplodonta* have been reported from strata of Tertiary age in California. Five species have been recorded living in marine waters between Bering Sea and San Diego, California, and eleven species have been reported from tropical and subtropical west American waters.

The genus is widespread and is represented by about 50 species in the seas at the present time. The greater number of species occur in warm waters. Most of these occur in quite shallow waters but at least one species, *Diplodonta (Felania) rosea* Reclúz, in the South Atlantic, was reported by Thiele and Jaeckel to occur at a depth of 155 meters. Lamy (759) published a paper dealing with the Recent species of *Diplodonta* in the collections of the Natural History Museum in Paris.

The genus name *Taras* Risso has been used by some authors instead of *Diplodonta* Bronn. Prashad (760) doubted that the type species of *Taras, T. antiquata* Risso, is even a member of the family Ungulinidae [=Diplodontidae] and Chavan (761) later discussed this question and gave good reasons for abandoning usage of *Taras* in favor of *Diplodonta.*

Key to Subgenera of *Diplodonta* (762)

A. Subglobose, nearly equilateral; white. . . . . *Diplodonta s. s.*

B. Compressed, inequilateral; usually covered by a dark periostracum. . . *Felaniella*

SUBGENUS *DIPLODONTA* S. S.

Diplodonta (Diplodonta) orbella Gould
Plate 55, Figure 11; Plate 57, Figures 9, 18

Lucina orbella Gould, Proc. Boston Soc. Nat. Hist., Vol. 4, p. 90, November, 1851. — Gould, Boston Jour. Nat. Hist., Vol. 6, p. 395, pl. 15, fig. 3 [two figs.], 1853.

Diplodonta orbella Gould, Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 238, 1888. "Pl. —San Diego well." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 134, pl. 18, figs. 8, 8a, 1903. (Lower San Pedro series, Deadman Island), 1903. "Pliocene. — San Diego well (Dall)." — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 38, pl. 3, fig. 4; pl. 25, figs. 5 and 6 (copy of Gould, 1853, pl. 16, fig. 3), 1924. Puget Sound to the Gulf of California. [Not the record from Bering Sea.] — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 124, pl. 6, figs. 5, 6, 1924. (Reproduction of figures by Gould, 1853). "Type locality, San Diego, California." "Range. Pribiloff Islands to the Gulf of California." [Not the record "Pribiloff Islands."] — Haas, Field Mus. Nat. Hist., Zool. Ser., Vol. 29, No. 1, pp. 8-12, figs. 3-7, 1943. La Jolla and Terminal Island, San Pedro, California. Recent.

Taras orbellus Gould, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 293, pl. 14, figs. 14a, 14b (Recent), 1931. "San Diego well, Balboa Park, San Diego (Dall)." Pliocene.

Type specimen. — No. 169271, Museum of Comparative Zoology, Harvard University (Johnson, U. S. Nat. Mus., Bull. 239, p. 119, 1964).

Type locality. — "San Diego, Lieut. Green." [California.]

Range. — "cf." Early Miocene; Pliocene to Recent. Recent from Monterey, California, to Punta Peñasco, Sonora, Mexico, in the Gulf of California, from low tide to 110 meters (60 fathoms), commonly nestling in holes in rocks, sometimes embedded in a "nest" which it builds.

Occurrence in San Diego Fm. — San Diego well (Cooper). L.A.M. 107, 305.

Original description. — T. parva, subglobosa, tenuicula, albida, concentricè inequiliter striata; apicibus medianis, haud eminentibus, absque lunulâ anticâ; lateribus ferè symmetricis; intus alba. Cardo valvae dextrae dentibus duobus quorum antico minore — valvae sinistrae dentibus duobus quorum antico bifido, postico perobliquo, instructus; dentibus lateralibus nullis; cicatricibus leviter impressis, palleali serie punctorum composito. Long. 4/5; alt. 6/8; lat. 1/2-5/8 poll. (Gould.)

Remarks. — Chavan (763) suggested that the present species might be referable to the subgenus *Timothynus* Harris and Palmer (764), the type of which is a species of late Eocene age.

Diplodonta orbella was cited by Cooper as occurring in the collection from the San Diego well and this record is apparently the basis upon which records from that locality (referred to Dall) were cited by later authors.

Two casts retaining traces of shell are present in the collection from Loc. 107 (LAM), the clay quarry at the end of Arroyo Drive. The larger one is 19.8 mm long, the convexity (one valve), 7.5 mm. The smaller one is 14.8 mm long. These agree so exactly in outline and convexity with Recent and fossil specimens of *Diplodonta orbella* that we identify them with that species.

Two right and one left valve, all incomplete, are present in the collection from Loc. 305 (LAM). The largest, a fragment of a highly convex right valve is 18.5 mm high.

A very large Recent specimen in the collections of the California Academy of Sciences, collected by Henry Hemphill at San Diego, California, is 34.5 mm long, 31.2 mm high, convexity (both valves together) 26 mm. They are more often about 25 to 30 mm in length.

Haas (765) discussed the "nest" building habit of this species by which it forms a protective covering of sand and mucus.

Diplodonta orbella has been recorded as occurring in beds of Pliocene age at other localitites than San Diego, such as in the Pico and Merced formations. *Diplodonta griesensis* Effinger (766) described from beds of middle Oligocene age in western Washington was compared with *D. orbella* and may be a precursor of Gould's species. "*Diplodonta* cf. *orbella* Gould" was cited by Loel and Corey (767) from Vaqueros beds, early Miocene, and Temblor strata, middle Miocene in age, and Bremner (768) recorded it under the same heading (identification by Corey), from Temblor beds on Santa Cruz Island, California. Judging from the literature, there is an element of doubt connected with many of the records of *D. orbella* from pre-Pliocene strata. Khomenko (769) cited the occurrence of *D. orbella* in Matchgar beds of lower Miocene age on the Schmidt Peninsula on Kamtschatka, but this identification appears doubtful. Records of this species from Japan are referable to other species.

The exact northern range of Recent *Diplodonta orbella* is not known with certainty. We have not observed Recent specimens from north of Monterey, California. Some of the Alaskan shells formerly referred to this species are referable to *Diplodonta impolita* Berry (770). We have observed specimens of this species from as far south as Cordell Bank (Lat. 38° N.), west of Point Reyes, California, in 40 meters (22 fathoms). *Diplodonta impolita* differs from *D. orbella* in the narrower, less inflated and more pointed umbos, more steeply sloping anterior dorsal margin, earthy texture and coarser incremental striae. Also the right anterior cardinal is vertically elongated in comparison to the analogous somewhat node-like tooth on Gould's species. Another northern form was described as *Diplodonta* (*Torelli* Jeffreys, var.?) *aleutica* by Dall (Proc. U.S. Nat. Mus., Vol. 23, p. 820, pl. 42, fig. 3, August 22, 1901) from Kyska Harbor, Aleutian Islands, in 8 fathoms.

SUBGENUS *FELANIELLA* DALL

Felaniella Dall, Jour. Conch., Vol. 9, No. 8, p. 244, October 1, 1899. "Type *Felania usta* Gld." — Lamy, Jour. de Conchyl., Vol. 65, No. 4, p. 338, 1921. "Type: *D. usta* Gould." — Habe, Gen. Jap. Shells, Pelecypoda, No. 2, p. 124, 1951. "Type species: *Felania usta* Gould (original designation)", figs. 256, 257.

Type species (by original designation). — *Felania usta* Gould [=*Mysia (Felania) usta* Gould, Proc. Boston Soc. Nat. Hist., Vol. 8, p. 31, March, 1861. "Inhabits Hakodadi Bay, in sandy mud, 8 fath." — Taki and Oyama, Paleo. Soc. Japan, Spec. Paper No. 2, p. 57, pl. 10, figs. 14-16; pl. 33, fig. 2, 1954 (as *Diplodonta (Felaniella) usta*). Japan. Pleistocene. — Kira, Col. Illus. Shells of Japan, p. 132, pl. 52, fig. 31, 1959 (as *Felaniella usta.*) Japan, Recent. — Chavan, Bull. Inst. Roy. Sci. Nat. Belgique, Vol. 38, No. 23, p. 10, 1962. Type: *Felania usta* Gould. Illustrated by Chavan, fig. 8. — Johnson, U. S. Nat. Mus., Bull. 239, p. 164, pl. 26, fig. 6, 1964 (as *Mysia (Felania) usta.*) Holotype].

Range. — Late Cretaceous to Recent (Chavan). Recent from the intertidal zone to 218 meters (119 fathoms).

Description. — Shell small, very inequilateral, slightly inflated; sculpture consisting of incrementals; ligament external; hinge of right valve consisting of a narrow anterior cardinal (3a) and a heavy, deeply bifid middle cardinal (3b); hinge of left valve consisting of a heavy, deeply bifid anterior cardinal (2) and a narrow posterior cardinal (4b). (Woodring, Carnegie Inst. Washington, Publ. No. 366, p. 130, p. 130, 1925.)

Remarks. — The shells of this subgenus differ from those of *Diplodonta s. s.* in that they are more compressed, less equilateral and in the Recent state they are covered with a dark periostracum.

Felaniella has been reported to range from Paleocene to Recent but in the western Americas it has not been reported earlier than in strata of Oligocene age (Tumey Sandstone). Most of the Recent species live in the Caribbean region and in the warmer waters of the eastern Pacific, but species also live in Japanese waters and one has been reported from South Africa.

Diplodonta (Felaniella) cornea Reeve
Plate 43, Figures 7, 13, 20

Lucina cornea Reeve, Conch. Icon., Vol. 6, *Lucina*, species 25, pl. 9, fig. 25, June, 1850.

Lucina nitens Reeve, Conch. Icon., Vol. 6, *Lucina*, species 50, pl. 9, fig. 50, June, 1850. "Hab. Isle of Muerte,

Bay of Guayaquil (in sandy mud at a depth of about eleven fathoms); Cuming."

Lucina sericata Reeve, Conch. Icon., Vol. 6, *Lucina*, species 55, pl. 9, fig. 55, June 1850. "Hab. — ?" — Adams and Reeve, Zool. Voy. Samarang, Moll., p. 80 p. 24, fig. 6, August, 1850. "Hab. Philippine Archipelago." [Locality believed to be erroneous.]

Diplodonta sericata Reeve, Woodring, Bramlette, and Kew, U. S. G. S., Prof. Paper 207, p. 83, pl. 36, figs. 11-14, 1946. Palos Verdes sand, San Pedro, California, Pleistocene.

Taras (Felaniella) sericatus Reeve, Hertlein and Strong, Zoologica, Vol. 31, Pt. 4, p. 131, pl. 1, fig. 10, 1947. "San Ignacio Lagoon, Lower California, to Guayaquil, Ecuador," Recent. [With synonymy.]

Diplodonta (Felaniella) sericata Reeve, Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 103, fig. 212, 1958. San Ignacio Lagoon, Lower California, to Ecuador.

Diplodonta (Felaniella) cornea Reeve, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 203, pl. 32, figs. 1, 1a, 1b, 1961. Gulf of California to Tumbez, Peru.

Type specimen. — Syntypes No. 1963 130/1-2, British Museum (Natural History).

Type locality. — "Hab. Gulf of Nicoiya (in coarse sand at a depth of from ten to thirteen fathoms); Cuming." Costa Rica.

Range. — Middle Pliocene to Recent. Recent from San Ignacio Lagoon, Lower California, to Punta Peñasco in the Gulf of California, Mexico, and south to Tumbez, Peru, in 7 to 73 meters (4 to 40 fathoms).

Occurrence in San Diego Fm. — L.A.M. P. 87: S8443, 305.

Original description. — Shell *Cardium*-shaped, a little higher than long, rather depressed, no lunule, concentrically impressly striated, hinge with two central teeth in each valve, one of which is bifid; whitish, covered with a light olive shinning horny epidermis. (Reeve.)

Remarks. — Four small, right valves and one left one, are present from Loc. 305 (LAM), near the Mexican boundary. The left valve is 10.5 mm long and 10.8 mm high. None of these valves is perfectly preserved but they agree in all observable details with Recent specimens of *D. cornea* of the same size. A fragment of a valve from the same locality, 17 mm long may be referable to this species.

One small right valve, slightly imperfect along the anterior margin, collected by Charles Sternberg in Balboa Park, is 11.5 mm long and 10.5 mm high.

A large Recent left valve from Loc. 27230 (CAS). Petatlan Bay, Mexico, is 22.6 mm long and 22.3 mm high. A specimen with paired valves from Loc. 23796 (CAS) Tepoca Bay, Gulf of California, is 20.5 mm long 20.2 mm high, convexity (both valves together 9.6 mm. Another more convex specimen from the same locality is 19.2 mm long, 19.4 mm high, convexity (both valves together) 10.3 mm.

Diplodonta cornea is here reported for the first time from the San Diego Formation. It was reported (as *Diplondonta sericata)* by Emerson and Hertlein (Trans. San Diego Soc. Nat. Hist., Vol. 13, No. 17, pp. 342, 349, 1964) from strata of Pliocene age on Carmen Island in the Gulf of California. It is well known from beds of Pleistocene age in southern California and in Lower California and it has been reported (771) as a fossil from an elevated beach in Peru.

This species is generally recorded under the name *Diplodonta sericata* Reeve. Hertlein and Strong pointed out that *D. cornea* has page priority and this nomenclature was also adopted by Olsson. Furthermore *D. sericata* was originally described without information as to the locality from which it came. Later Adams and Reeve cited it from the Philippine Islands. Finally Carpenter and Dall, considered it to be a west American species. After consideration of the history of this species we conclude that it is best to use the earliest name applicable to this form.

The present species is very similar to *Diplodonta parilis* Conrad (772), described from Oregon in beds of middle Miocene age. Some authors have recorded *D. cornea* (as *D. sericata*) as a subspecies of *D. parilis*.

A series of specimens of *D. parilis* from Miocene strata at Loc. 166 (CAS), Clatskanie, Oregon, and casts of the specimens from the Astoria Formation in western Washington which were illustrated by Etherington (773), are all slightly more elongated anteriorly-posteriorly and the ends are a little more flattened that are those of *D. cornea*. Some specimens from beds of late Pliocene age in San Joaquin Valley appear to be inseparable from *D. cornea*, others are hardly separable from *D. tellinoides* Reeve (774).

Diplodonta harfordi Anderson (775) described from beds of probable middle Miocene age in San Joaquin Valley has a straighter anterior dorsal margin than either *D. parilis* or *D. cornea*.

Diplodonta stephensoni Clark (776), described from the San Ramon Formation of late Oligocene or early Miocene age, near Walnut Creek, California, was said to differ from *D. "serricata"* [= *D. cornea*] in details of the hinge.

Diplodonta candeana d'Orbigny, originally described from Cuba, also is similar to *D. cornea*. Chavan (1962, p. 12) mentioned a resemblance between *D. "sericata"* [=*D. cornea*] and species in the subgenus *Zemysia* Finlay, 1927, with the type *Z. zelandica* Gray, 1835.

FAMILY THYASIRIDAE DALL (777)

Shell roundly trigonal, earthy, thin; posterior side with one or more radial depressions; ligament in a groove, partly external, hinge edentulous or in the right valve with a subobsolete pseudo-tooth; muscle impressions elongated; pallial line simple; margin smooth. Triassic (Chavan). Cretaceous to Recent.

Remarks. — This family is represented in the eastern Pacific by *Thyasira* and *Axinopsida*. One species of each is present in the San Diego Formation.

The greater number of species in this family live in boreal waters but a number of species are found in tropical waters.

The genus *Adontorhina* Berry (778) was placed tentatively, in the family Thyasiridae. However, the lack of a posterior radial depression, the hinge with ridged plates, and the granular or plated posterior dorsal margin, are shell characters differing from other members of this family.

Key to Genera of Thyasiridae

A. Shell with one or more furrows on posterior portion . . . . . *Thyasira*

B. Shell discoidal, lacking furrows on posterior portion . . . . . *Axinopsida*

GENUS *THYASIRA* LEACH IN LAMARCK

Thyasira Leach in Lamarck, Hist. Nat. Anim. s. Vert., Vol. 5, p. 492, July, 1818. Sole species cited, "*Thyasira flexuosa.* Leach." Ref. to "*Tellina flexuosa.* Maton Act. Soc. Linn. 8. p. 56, n. o. 16." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, Pt. 6, p. 1335, October, 1903. Sole species originally cited, *Tellina flexuosa* Montagu. — Lamy, Jour. de Conchyl., Vol. 65, No. 3, p. 290, 1921. Type, *Tellina flexuosa* Montagu. Fig. (p. 291).

Conchocele Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 27, February, 1866. Type (by virtual monotypy): *Conchocele disjuncta* Gabb, p. 28, pl. 7, figs. 48, 48a, 48b. "From Dead Man's Island, near San Pedro Bay; from a hard sandstone associated with two or three previously known Tertiary Fossils. Probably Miocene." [Late Pliocene or early Pleistocene.] [*Venus bisecta* Conrad mentioned in the text was considered as "probably belonging to this genus." This equivocal statement leaves *C. disjuncta* as the sole species available as type of the genus according to the present rules of nomenclature. For a discussion of this species, see Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 194, pl. 15, fig. 1, 1930. — Woodring, Bramlette, and Kew, U. S. G. S., Prof. Paper 207, p. 83, pl. 33, fig. 5, 1946. "*T. disjuncta* is the type of *Conchocele.*"]

Type species (by monotypy). — *Thyasira flexuosa* Montagu [=*Tellina flexuosa* Montagu, Test. Brit., p. 72, 1803, "It is plentiful in the sand of Falmouth harbour, and not uncommon on the south coast of Devonshire." Also, "Cornwall". Illustrated by Forbes and Hanley, Hist. Brit. Moll., Vol. 2, p. 54, pl. 35, fig. 4, 1852. — Jeffreys, Brit. Conch., Vol. 2, p. 247, pl. 5, fig. 6, 1863; Vol. 5, pl 179, p. 33, figs. 1, 1a, 1869. — Thiele, Handbuch Syst. Weichtierkunde, Bd. 2, p. 864, 1935. See also Lamy, 1921, p. 292, fig. p. 291; Tebble, British Bivalve Shells [Brit. Mus. (Nat. Hist.)]. pp. 16, 79, text-fig. 5a, 5b, 1966.]

Range. — Cretaceous to Recent. Recent world wide from low tide to 10,004 meters (5470 fathoms) (779.)

Description. — Shell subcircular to subquadrate, moderately inflated, beaks strongly curved anteriorly; lunule consists of an impressed area below the beaks sometimes indistinct, escutcheon long and narrow; posterior side furrowed or sharply angulated; ligament usually partly external; sculpture of growth lines only; hinge lacking teeth but sometimes below the umbo of the left valve there is a fold in the hinge plate and behind this a slight projecting pseudo-tooth; muscle impressions lucinoid; pallial line simple; margins smooth.

Remarks. — The genus *Thyasira* occurs in western North America in strata of Cretaceous age and from Oligocene to Recent, but no species have been described from beds of Eocene age in this region. One species has been recorded as occurring in the San Diego Formation. Popenoe (780) cited the occurrence of casts of "*Thyasira*" in brown, calcareous, silty sandstone dredged apparently on "Coronado Bank". Nothing further is known concerning the species represented by the casts or the age of the strata containing them.

This genus is represented by a number of Recent species and is widespread in the seas at the present time, mostly in cool waters. Many of the species are small or of moderate size, but a specimen of *T. disjuncta* collected by G. D. Hanna on the shore of Macleod Bay, Montague Island, Alaska, is 85 mm long, 69.5 mm high, and the convexity (both valves together) 55.4 mm. Hägg (781) cited a fossil form identified as *Thyasira bisecta* from beds of late Tertiary age in Spitzbergen, the largest of which was 85 mm long. Judging from the known records of size, Hägg concluded that this species attained a larger size in warmer rather than in very cold waters.

Most of the known living species of *Thyasira* were discussed or listed by Lamy (1921, pp. 289-318). Dall (782) mentioned nine species living in the eastern Pacific. A monographic study of this group would probably result in a reduction of this number. The Recent species living in New Zealand were given special attention by Fleming (783) who place *Prothyasira* Iredale, 1930, in the synonymy of *Thyasira.* Antarctic species of this genus were discussed by Soot-Ryen (784). The Cenozoic species of *Thyasira* occurring in Japan were discussed by Yabe and Nomura (785) and species from the beds of Tertiary age in Sakhalin and Kamtschatka were described and illustrated by Slodkewitsch (786). Species of *Thyasira* of Cretaceous age from the western interior of North America were described and illustrated recently by Kauffman (787). In this paper he included a general discussion of this genus and its occurrence both Recent and as a fossil.

Thyasira gouldii Philippi
Plate 43, Figures 17, 21

Lucina flexuosa Montagu, Gould, Rept. Invert. Massachusetts (Cambridge), p. 71, fig. 52, 1841.

Not *Tellina flexuosa* Montagu, Test. Britannica; or Nat. Hist. British Shells, Pt. 1, p. 72, 1803. "Cornwall"; also "in the sand of Falmouth harbour" and "south coast of Devonshire."

L[ucina]. *Gouldii* Philippi, Zeitschr. f. Malakozool., Jahrg. 2, p. 75, May, 1845. [Description pp. 74-75. In a review of Gould's Report on the Invertebrata of Massachusetts.]

Cryptodon Gouldii Philippi, Binney's edit. of Gould's Rept. Invert. Massachusetts (Wright and Potter: Boston), p. 100, fig. 52, 1870. Massachusetts Bay and neighboring region.

Cryptodon flexuosus Montagu, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "well at San Diego," "Pliocene." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. San Diego well. — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. Calif. State Mineral., p. 237, 1888. "San Diego well." — Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 85, 1889. Dall's record

(1874) cited. — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited.

Not *Cryptodon flexuosus* Montagu [=*Tellina flexuosa* Montagu, 1803].

Axinus gouldii Philippi, Sars, Bid. Kundsk. Norges Arktiske Fauna I, Moll. Reg. Arct. Norvegiae (Christiana) p. 60, pl. 19, figs. 6a, 6b, 1878. Various localities in northern Atlantic.

Thyasira gouldii Philippi, Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, pp. 786, 790, 1901. Greenland to Stonington, Connecticut, in 5 to 400 fathoms; on west coast from Metchigme Bay, Bering Strait, south to Puget Sound, in 8 to 11 fathoms. Also Pliocene of San Pedro, California. — I. S. Oldroyd Publ. Puget Sound Biol. Sta., Vol. 4, p. 37, pl. 42, fig. 5, 1924. "Bering Sea to San Diego, Calif.; Atlantic." [Reproduction of figure from Packard, 1918.] — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 120, pl. 34, fig. 5 (Recent), 1924. "Pliocene at San Diego well." Also other localitites. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 282, 1931. "San Diego formation of the San Diego well in Balboa Park. San Diego (Dall, 1874)." — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) of *Cryptodon flexuosus* Montagu. — Morris, Field Guide to Shells (Houghton Mifflin Co.: Boston) p. 36, pl. 8, fig. 15, 1952. "from the Bering Sea to San Diego, California." — Ockelmann, Mar. Lamell., in Zool. East Greenland, Medd. om Grønland Vol. 122, No. 4, p. 100, pl. 2, figs. 4, 5, 1958. East Greenland and other localities in 2-3 to 385 meters Panarctic.

Thyasira gouldi Philippi, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 136, 1903. "San Diego well (Cooper)." — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 264, pl. 20 fig. 5, 1918. "Bering Strait to San Diego (Dall)."

Type specimen. — Reported to be in the State Museum, Albany, New York, by I. S. Oldroyd, 1924, but according to R. I. Johnson (written comm., October 27, 1964), no specimens of this species were found in any of Gould's collections examined by him.

Type locality. — "It inhabits deep water, and is very frequently taken from codfish, caught in Massachusetts Bay." (For "*Lucina flexuosa*" Montagu of Gould, 1841, not *Tellina flexuosa* Montagu, 1803.)

Range. — Pliocene to Recent. Recent from Bering Strait to San Diego, California, in 15 to 203 meters (8 to 111 fathoms). Atlantic from Greenland to Connecticut, in 9 to 732 meters (5 to 400 fathoms) Dall (1901); to North Carolina (Richards). According to Ockelmann (1961), this species "is uncommon at depth exceeding 100 m and even depths of about 50 m often only smaller specimens are found."

Occurrence in San Diego Fm. — San Diego well (Dall). L.A.M. 107, 305, 305A. U.C.L.A. 294.

Original description. — "Von *Lucina flexuosa* sagt Gould, p. 72: 'there can be no doubt, that this is identical with the British shell, though the specimens I have seen are much smaller, than the foreign specimens usually are'. Bei einer aufmerksamen Betrachtung findet man idessen, ausser dem sehr auffallenden Unterschied in der Grösse — die amerikanische Art ist 1 1/2", die englische 4"' gross — folgende Verschiedenheiten: 1) die amerikanische Art ist schiefer, die hintere Seite, welche die beiden Falten trägt, kürzer; 2) dieselbe hat keine vertiefte Lunula, und ist namentlich der Schlossrand vorn nicht gerade oder selbst concav, sondern von Anbeginn an convex; dagegen geht 3) eine breite seichte Furche nach dem vordern Winkel hin, von der die englische Art keine Spur zeigt. Ich schlage vor, die amerikanische Art *L. Gouldii* zu nennen. Sie gehört übrigens in das Sowerby'sche Genus *Axinus*, welches mit dem Turton'schen Genus *Cryptodon* identisch ist, so wie mit dem von mir aufgestellten Genus *Ptychina*". (Philippi.)

Remarks. — This species was reported from the San Diego well by Dall in 1874. Subsequent records citing it from that locality apparently were based upon Dall's record. Seven fairly well preserved specimens in the collections of the University of California at Los Angeles, and a few others, mostly fragmental, in the collections of the Los Angeles County Museum, are from the San Diego Formation from near the Mexican boundary. The largest specimen from Loc. 294 (UCLA) is 9.4 mm long and 8 mm high. A Recent large left valve from Winter Harbor, British Columbia, in the collections of the California Academy of Sciences, is 9.6 mm long and 10.1 mm high.

These fossils appear to be identical with specimens of *Thyasira gouldii* from the Atlantic coast. Dr. A. M. Keen compared the fossils with Recent shells in the collection at Stanford University and concluded that *T. gouldii* could be considered to be a subspecies of the north European *T. flexuosa* Montagu. This was virtually the same opinion as that of Odhner (788) who noticed minor differences between the European species and specimens of *T. gouldii* from Alaska. The shell of the European species was said to be more fragile and white in comparison to Alaskan specimens of *T. gouldii* which were rougher, thicker and of a dirty white color.

The name *Lucina gouldii* was proposed by Philippi in 1845 (for "*Lucina flexuosa*" Montagu, described and illustrated by Gould) in a review of Gould's paper dealing with the Invertebrata of Massachusetts, 1841.

Binney (1870) stated that Philippi's criteria for separating *T. gouldii* from the European *T. flexuosa* are valid, namely, "ours is much smaller, more oblique, the hinder end on which the folds are situated is shorter, the lunule is less deep, and the anterior margin is not concave, but rather convex. Indeed the disparity in size is so great as scarcely to suggest a comparison."

A study of north Atlantic and Arctic species of *Thyasira* led Ockelmann (789) to believe that the east American forms described a *Cryptodon plana* Verrill and Bush (791) "must be regarded as junior synonyms of *T. gouldii* (Philippi)". Eyerdam's record of *T. gouldii* from Dryer Bay, Alaska, was later corrected to *T. cygna* Dall (792). The species from Japan cited under the name of *Thyasira gouldii* was named *Thyasira tokunagai* by Kuroda and Habe (793). According to Habe (794) the Japanese shell is smaller and has a narrower posterior flexure.

The group of *Thyasira flexuosa* (to which *T. gouldii* belongs) has been reported from Miocene to Recent in Europe. This group is widely distributed in the seas at the present time. *Cryptodon marionensis* E. A. Smith (795) from the Antarctic region was said by its author to be a southern form of *T. flexuosa* and *T.*

gouldii. Fleming (1950, p. 251) in his discussion of the Austral species, *T. peroniana*, stated: "It is indeed possible to consider *peroniana* and its races as subspecies of the wide-ranging *flexuosa* Mont."

Thyasira gouldii has been cited as occurring at several localities in beds of Pliocene age in southern California. Some of these occurrences are as follows: Potrero Canyon, 1/4 mile south of the Palisades post office, by Woodring (796); at Fourth and Broadway in Los Angeles by Soper and Grant (797); questionably at the Waldorf Asphalt Mine in the Foxen Mudstone in the Santa Maria district by Woodring (798). Woodring mentioned that the anterior end of specimens from that district is longer than on Recent specimens from California. *Thyasira gouldii* also has been recorded occurring in Pleistocene beds in California and Richards (799) has recorded it from beds of Pleistocene age in Maine, in Vermont,in Montreal, in Quebec, and in Newfoundland.

Valentine (800) considered *T. gouldii* to be a member of a "*Lucinoma annulata-Turcica caffea* community" in beds of Pleistocene age in southern California, deposited probably at a depth of 27 to 46 meters (15 to 25 fathoms). A "*Thyasira gouldii-Neptunea tabulata*" community is said to live in the "shallow outer sublittoral, 20-25 fathoms, silt and clay bottom."

Thyasira barbarensis Dall (801) appears to be quite distinct from *T. gouldii.* At the time of description of *T. barbarensis* Dall stated, "This fine species is nearer *C. sarsii* [802] than any other, but has decidedly more elevated and narrower beaks." He also included a description of the soft parts of his new species. Burch mentioned that *T. barbarensis* usually lives in colonies and Valentine (1961, p. 323) stated that it was found rather commonly on a mud bottom in 38-40 meters (21-22 fathoms) in Santa Monica Bay in southern California.

GENUS *AXINOPSIDA* KEEN AND CHAVAN

Axinopsis Sars, Bid. Kunds. Norges Fauna. I. Moll.Reg. Arcticae Norvegiae (Christiana), p. 63, 1878. Sole species, *Axinopsis orbiculata* Sars.

Not *Axinopsis* Tate, 1868, a new name for *Schizodus* King, 1844.

Axinopsida Keen and Chavan, in Chavan, Compt. Rend. Somm., Soc. Géol. Franc, No. 12, p. 210, June 18, 1951. "Type: *A. orbiculatus* Sars." — Keen, Min. Conch. Club South. California, No. 116, p. 4, December 1951. "Type (by original designation): *A. orbiculatus* (Sars)."

Type species (by original designation). — "Type: *A. orbiculatus* Sars" [=*Axinopsis orbiculata* Sars, 1878, p. 63, pl. 19, figs. 11a-d, "Vadsø paa 600-100 F. D." Also, from Vardø and Bodø, Norway. — Soot-Ryen, Norges Svalbard — og Ishavs — Undersøkelser, Medd. No. 43, p. 14, pl. 1, fig. 7, 1939. "Off East glacier, Cape Flora, 4 fathoms," and "Gunther Sound (Bay), 10 fathoms," Franz Josef Land. — Ockelmann, Medd. om Grønland, Bd. 122, No. 4, p. 111, pl. 2, figs. 7, 8, 1958. East Greenland and other localities. — MacGinitie, Proc. U. S. Nat. Mus., Vol. 109, No. 3412, p. 172, pl. 20, fig. 2, 1959. Pt. Barrow, Alaska, in 36 meters (120 feet).]

Range. — Middle Pliocene to Recent. Recent, Arctic to Todos Santos Bay, Lower California, Mexico, and to Japan; Norway and Greenland to Cape Hatteras, North Carolina, in Atlantic; Antarctic, in 7 to 594 meters (4 to 325 fathoms). Cited from depths of 10,607 meters (5850 fathoms).

Description. — Shell discoidal, tumid in the middle, compressed towards the margins; umbones slightly prominent; no external ligament; valves thin, pellucid, white, concentrically striate; cardinal tooth in the right valve obtusely elevated, recurved, in the left valve elongated, subhorizontal; cartilage narrow. (For *Axinopsis.* Tryon, G. W., Jr., Structural and Systematic Conchology, Vol. 3, p. 216, 1884.)

Remarks. — The members of this genus live chiefly in Arctic and boreal waters but in the eastern Pacific this genus occurs south to Todos Santos Bay, Lower California, Mexico.

The shells of *Axinopsida* are small. The number of described species and subspecies is not large but the separation of the various forms has not been entirely satisfactory.

Genaxinus Iredale, type *Thyasira albigena* Hedley, is a similar genus but the hinge of species of this austral group is virtually edentulous (803).

Axinopsida serricata Carpenter
Plate 44, Figures 17, 18

Cryptodon serricatus Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 602, 643, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 88, 129, 1872. Indicated as from "Puget's Sound and the neighbourhood"; "Vancouver Island, Straits of S. Juan de Fuca, and adjoining shores of Washington Territory, formerly known as 'Oregon'." Also "?Cat. Is. Cp. 120 fm." — Carpenter, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, p. 57, 1865. "Hab. — In sinu Pugetiano legit Kennerly: in insulâ Vancouver, Swannii Indianuli."

Axinopsis sericatus Carpenter, Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1237, pp. 791, 819, pl. 40, fig. 2 (Puget Sound), 1901. "Kyska Island, Aleutians, south to Puget Sound and Catalina Island, California, in 2 to 120 fathoms." — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 38, pl. 26, fig. 4, 1924. Puget Sound; Departure Bay, British Columbia. Range: Aleutian Islands, Alaska, to Catalina Island, California. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 123, pl. 4, fig. 4, 1924. Range same as in preceding reference.

Axinopsida serricata Carpenter, K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 84, pl. 7, figs. 16-18, 1958. "Puget Sound, Washington (type)." Range same as given by Dall.

Type specimen. — "Lectotype. — U. S. National Museum, No. 5249" (Palmer, 1958.)

Type locality. — "Puget Sound, Washington (type)." (Palmer, 1958.)

Range. — Middle Pliocene to Recent. Recent from the Aleutian Islands, Alaska, to Todos Santos Bay, Lower California, in 4 to 219 meters (2 to 120 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A.

Original description. — Small, circular, flat; epider-

mis silken. (Carpenter.)

Supplementary description: C. t. parvá, subplanatâ, subcirculari tenui, albâ, haud flexuosâ; epidermide tenuissimâ, vix stramineâ, serricatâ, indutâ; laevi, seu lineis incrementi vix ornatâ, nitente; suborbiculari, seu ventraliter productâ; marginibus undique valde et regulariter rotundatis, regione lunulari incurvatâ; umbonibus attice hamatis; lunulâ planatâ, haud exacte difinitâ; intus, ligamento tenui, omnino celato; dentibus cardinalibus in utrâque valvê uno, extante, lateralibus nullis; cicatricibus adductoribus subovalibus, haud prolongatis; lineâ palii à margine ahud crenato satis remotâ: Long. .16, lat. .18, alt. .1 (Carpenter, 1865.)

Remarks. — Three left and one small right valve of this species are present in the collection from Loc. 305 (LAM) from near the Mexican boundary. The largest of these, a left valve, is about 3.4 mm long and 3.1 mm high. The small right valve is higher than long. One right and two fragmental left valves are present in the collection from Loc. 305A (LAM).

The lectotype was described by Palmer as slightly higher than long, about 4.5 to 4 mm. Burch (804) questioned whether *Axinopsis viridis* Dall (805) could be separated from *A. serricata.* Dall illustrated two shells under these names and described *A. serricata* as "ovate" and *A. viridis* as "orbicular." Willett (806), and Woodring evidently believed that they could separate the two species on the basis of shape. Palmer (1958) however, pointed out that Carpenter originally described *A. serricata* as "circular." Furthermore in various collections she found specimens, some of which were round, others elongate, which were identified in some cases as *Axinopsis viridis* Dall and in others *A. serricata.*

We have examined Recent specimens from Alaska, Puget Sound, Monterey, and Redondo Beach, California. Most of these are circular in outline. A large one from Loc 18545 (CAS), Unalaska, is 3.9 mm long and high. Dall and others have indicated that the geographic ranges of *A. serricata* and *A ovata* are nearly the same. We are inclined to share the doubts of Burch and Palmer that more than one species of *Axinopsida* lives in the northeastern Pacific.

Axinopsida serricata was reported by Willett (807) from strata of late Pliocene age at Fourth and Broadway streets in Los Angeles; in the Lomita Marl, Hilltop Quarry, Los Angeles Co. (Valentine and Mead), and it also has been reported from beds of Pleistocene in age in British Columbia (808). *Axinopsida viridis* Dall was reported by Woodring (809) from the Waldorf asphalt mine in Santa Barbara Co. That species also has been reported from beds of late Pliocene age in Los Angeles Co. as well as in beds of Pleistocene age in Alaska, and at San Pedro, California.

SUPERFAMILY CARDIACEA OKEN (810)
FAMILY CARDIIDAE OKEN (811)

Shell substance cellulo-crystalline, with the external layer more or less tubular; with a variable epidermis; valves equal free, gaping slightly behind, the beaks prosocoelous, the margins usually serrate or radially straited; adductor scars subequal, the pedal distinct and usually distant; ligament and resilium parivincular, external, set in a groove, short; area obscure; the complete armature of the hinge includes an anterior and posterior lateral in the left, and two anterior and one posterior lateral in the right valve (any or all of which may be absent), the cardinal formula is $\frac{L\ 1010}{R\ 0101}$, the teeth simple, smooth never bifid, one cardinal in each valve usually persistent, the others inconstant. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 3, p. 549, 1895.). Late Triassic to Recent.

Remarks. — The members of this family are worldwide in distribution from the Arctic to the tropics in marine and in brackish water. A number of supraspecific units have been proposed for the members of the Cardiidae. These together with their type designations have been assembled in a paper by A. M. Keen (812)

Various papers concerning Cenozoic species of this family have been published. Among the more recent ones may be mentioned one by Marwick (813) dealing with the species of New Zealand, one by Tremlett (814) dealing with English Eocene and Oligocene species, and one by Sieber (815) dealing with Miocene species in the Vienna basin.

A synopsis of Recent west American species was published by Dall (816), and Hertlein and Strong (817), Keen (818), and Olsson (819) discussed many of the Recent tropical west American species. Notes by Burch (820) and others on the species occurring in the region between the Bering Sea and San Diego, California, occur in the Minutes of the Conchological Club of Southern California. A useful paper dealing with the species of Cardiidae living in the west Atlantic region was published by McLean (821).

Key to Genera and Subgenera of Cardiidae

A. Shell large, with coarse radial ribs with roughly uniform secondary sculpture.

  a. Beaks strongly prosogyrate . . . *Clinocardium*
  aa. Beaks not prosogyrate or only slightly so.

    b. Ribs lacking nodes . . . (subgenus) *Cardium s. s.* (822)
    bb. Ribs in central portion bear elongated nodes on posterior and sometimes to a lesser degree on anterior side . . . (subgenus) *Dallocardium*

B. Shell small to moderate size, with rather fine radial ribs of which those on posterior fourth of valves differ in secondary sculpture . . . . . *Nemocardium*

  a. Posterior ribs decidedly wider than the others . . (subgenus) *Nemocardium s. s.* (822)
  aa. Posterior ribs not decidedly wider than the others and crossed by concentric lamellae . . . . . (subgenus) *Keenaea*

GENUS CARDIUM LINNAEUS

Cardium Linnaeus, Syst. Nat., ed. 10, p. 678, 1758.
Cardium costatum Linnaeus, first of a number of

species described by Linnaeus. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1069, December, 1900. Earlier authors cited. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 302, 1931. Type (designated by Children): *Cardium costatum* Linnaeus.

Type species (designated by Children, Quart. Jour. Sci. Lit. Arts, Vol. 14, p. 315, pl. 6, fig. 59, 1823). — *Cardium costatum* Linnaeus [Syst. Nat., ed. 10, p. 678, 1758. "Habitat. . . ." Ref. to Rumphius, Mus., pl. 48, fig. 6; Gaultieri, Test., pl. 72, fig. D; Argenville, Conch., pl. 26, fig. A, and "Column. purp. 26, t. 27." Illustrated by Reeve, Conch. Icon., Vol. 2, *Cardium*, sp. 11, pl. 2, fig. 11, 1844. " Hab. East Coast of Africa." See discussion of this species by Dodge, Bull. Amer. Must. Nat. Hist., Vol. 100, art. 1, p. 54, 1952.]

Range. — *Cardium* s. s., Miocene to Recent. Cosmopolitan. Recent from the intertidal zone to 200 meters (109 fathoms), occasionally deeper. Subfamily Cardiinae, Late Triassic to Recent (Keen).

Description. — Shell ventricose, close or gaping posteriorly; umbones prominent, subcentral; radiately ribbed; margins crenulated; pallial line more or less sinuated.

Animal with the mantle-margins plaited; siphons clothed with tentacular filaments, anal orifice with a tubular valve; branchial fringed; foot long, cylindrical, sickle-shaped, heeled. (Tryon, G. W., Jr., Structural and Systematic Conchology, Vol. 3, p. 192, 1884.)

Remarks. — This genus, construed in a broad sense, is represented by about 200 species in all oceans. Some species are quite tolerant of brackish water, where the shell becomes smaller and thinner (823). Most of the species occur in shallow to moderate depths, but some of them occur down to depths of 183 meters (100 fathoms) or more.

When submerged, the species of *Cardium* lie covered with sand or sandy mud with only the edges of their shells or only their siphons reaching the water. However, they can move about by means of a strong muscular foot and have been reported to be able to leap several meters at a bound.

Sculpture of the shells is predominately radial although the valves of certain groups are nearly smooth or may have partial concentric ornamentation.

About a dozen and a half species have been described occurring in Tertiary strata in western North America and over a dozen are recorded living in marine waters between the Bering Sea and San Diego, California. About two dozen species and subspecies have been reported as living in tropical and subtropical west American waters.

Only three species, one referable to *Cardium (Dallocardia)*, one to *Clinocardium*, and one to *Nemocardium*, are known with certainty to occur in the San Diego Formation.

SUBGENUS *DALLOCARDIA* STEWART

Dallocardia Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, pp. 37, 264, August 9, 1930.

Type species (by original designation). — "type species, *Cardium quadrigenerium* Conrad" [= *Cardium quadragenarium* Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 230, pl. 17, fig. 5, 1837. "Inhabits near Sta. Barbara; rare."]

Range. — Late Oligocene (San Ramon Formation) to Recent. Recent from the intertidal zone to 137 meters (75 fathoms).

Description. — Differs from *Trachycardium* in the broader (longer) outline and in that the elongated nodes on the central ribs are placed diagonally on the posterior (and on some specimens also, to a lesser degree, on the anterior) sides.

Remarks. — *Trachycardium* Morch (824) differs from *Dallocardia* in that the shell is narrower in comparison to the height, the hinge is relatively coarser and especially in that the scales on the central ribs loop over the entire top of the ribs.

Stewart mentioned that *Dallocardia* and *Trachycardium* are not known to occur earlier than Neogene time. More recently Eames (825) questioned whether or not certain species in the Eocene strata of Pakistan might be referable to *Trachycardium*. Gardner (826) gave the range as Cretaceous to Recent, and Stephenson (827) referred a species from the Cenomanian, Cretaceous, of Texas, to Mörch's unit. Finlay and Marwick (828) indicated that in New Zealand, *Trachycardium* is restricted to the Waitotaran Stage, early Pliocene.

Cardium (Dallocardia) quadragenarium Conrad
Plate 46, Figures 18, 20, 23

C[ardium]. quadragenarium Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 230, pl. 17, fig. 5, 1837. — Weymouth, State Calif. Fish Game Comm., Fish Bull. No. 4, p. 28, pl. 5, fig. 1, 1924. "off shore from Santa Barbara southward."

Laevicardium (Trachycardium) quadragenarium Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 306, pl. 19, fig. 15, 1931. Various localities, early Miocene to Recent.

Trachycardium quadragenarium Conrad, Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 55, fig. 21, 1953. "Monterey Bay, California, to Cape San Lucas, Baja California," Recent. — Abbott, American Seashells (D. Van Nostrand Co., Inc.), p. 398, pl. 31, fig. A, 1954. "Santa Barbara to Lower California."

Type specimen. — Location unknown to the present authors.

Type locality. — "Inhabits near Sta. Barbara; rare."

Range. — Late Miocene to Recent. Recent from Monterey Bay, California (A. G. Smith and Gordon, 1948), to Todos Santos Bay, Lower California, from the intertidal zone to 137 meters (75 fathoms). In sandy mud with the edges of the valves projecting above the surface, in sloughs and sheltered waters of the open coast.

Occurrence in San Diego Fm. — C.A.S. 1402. L.A.M. 305, 305A.

Original description. — Shell cordate, subequilateral, ventricose, thick; ribs forty to forty-two, prominent, subangular, flattened at the sides with a series of small tubercles, which, on the anterior side, are largest, and placed in the middle of the ribs, but elsewhere on the posterior angular margin of the ribs; umbo broad,

prominent; beaks not oblique; tubercles elevated on the posterior slope; colour pale yellow, with fulvous spots and zones; posterior margin direct, deeply serrate. Height, three inches. (Conrad.)

Remarks. — Two specimens of this species are present in the Academy's collection from Balboa Park. A left valve, the better preserved of the two, is 51 mm high and 49.8 mm long. Although the preservation is imperfect, the shape, number of ribs (41 visible) and the spiny sculpture all correspond well with Recent specimens of *Cardium quadragenarium* of the same size. The umbonal portion of two valves, the large one about 50 mm high, and some other fragments, were collected at Loc. 305 (LAM) near the Mexican boundary. These valves also are similar to Recent specimens. A large Recent specimen from San Pedro, California, in the Hemphill collection in the California Academy of Sciences, is 124 mm long and 112 mm wide.

A fossil from Pliocene beds in Elsmere Canyon was described by Arnold as "*Cardium quadrigenarium* Conrad var. *fernandoensis.*" (829). It was said to differ from the typical species as follows: "This variety is more oblique, has narrower umbones, is relatively less in diameter, and has fewer and less prominently spinose ribs than the typical form." We have examined a cast of Arnold's type specimen. It possesses 36 ribs and agrees with Arnold's description of this form.

The species described as *Trachycardium sagaseri* (830) by Adegoke, from the Etchegoin Formation, is said to possess about 28 radial ribs.

The early Miocene species described as *Cardium (Trachycardium) vaquerosensis* Arnold (831) was said to differ from the form *fernandoensis* as follows: "It differs from *C. quadrigenarium* Conrad, var. *fernandoensis* Arnold, from the lower Pliocene, by being much larger, more convex, having more prominent umbones, and having fewer, wider, deeper, steeper-sided interspaces." The type specimen has 34 radial ribs. As mentioned by Arnold, *C. vaquerosensis* is almost certainly the precursor of *C. quadragenarium.*

The species described as *Cardium (Trachycardium) gorokuense* Nomura (832) was compared by its author with *C. quadragenarium.* The Japanese fossil is a very small shell 3.7 mm in length and in general features resembles small specimens of Conrad's species. However, the ornamentation of the ribs appears to be different as it is said to bear closely set concentrically arranged scales, those on the posterior area somewhat spinose.

[*Cardium (Mexicardia) procerum* Sowerby]

Cardium procerum Sowerby, Proc. Zool. Soc., London for 1833, p. 83, September 8, 1833. — Reeve, Conch. Icon., Vol. 2, *Cardium*, sp. 51, pl. 10. fig. 51, 1844. Original locality cited. — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11, 1878. Later Tertiary of San Diego. Also Recent. — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 232, 1888. "Pl. — San Diego well." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1091, 1900. "From the Pliocene of the well in the City Park at San Diego, California."

Type specimen. — Syntypes in British Museum (Natural History).

Type locality. — "Hab. in Americâ Centrali. (Real Llejos)." "Found in coarse sand in from four to six fathoms water."

Range. — Pliocene to Recent, Costa Rica, and Ecuador; late Pleistocene to Recent in Lower California; late Pleistocene in southern California. Recent from Lagoon Head, Lower California. (Lat. 28° 15' N., Long. 114° 07' W.), and the Gulf of California, to Bahía de la Independencia (Lat. 14° 15' S.), Peru (Olsson).

Occurrence in the San Diego Formation. — San Diego well (Cooper; Dall).

Remarks. — This species was not cited by Dall in his original list (1874) of the species found in the San Diego well. The first record of *Cardium procerum* in beds which might be presumed to be of Pliocene age at San Diego is that of Dall in 1878 in which he referred to its occurrence in "later Tertiary deposits." Cooper, 1888, cited it as occurring in the Pliocene strata of the San Diego well as did Dall in 1900. We do not know what specimens formed the basis of these records nor have we seen any specimens from beds of Pliocene age in that region.

Most authors consider the range of *Cardium procerum* to be from the southern portion of the outer coast of Lower California, and the Gulf of California, to Peru. Keen (1958, p. 116) recognized a northern form, said to be characterized by its triangular ribs (often with fine nodes along the crest) separated by linear interspaces, under the name of *Trachycardium (Mexicardia) panamense* Sowerby. The generally more southern form said to be characterized by its smooth, rounded ribs separated by rather wide, flat interspaces, was referred to *Trachycardium (Mexicardia) procerum* Sowerby. However, many authors consider these forms to be referable to a single species (see Olsson, 1961, p. 247).

GENUS *CLINOCARDIUM* KEEN

Clinocardium Keen, Trans. San Diego Soc. Nat. Hist., Vol. 8, No. 17, p. 119, March 12, 1936. — Habe, Gen. Jap. Shells, Pelecypoda No. 2, p. 150, 1951. "Type species: *Cardium nuttalii* Conrad, 1837."

Type species (by original designation). — "Genotype: *Cardium nuttallii* Conrad, 1837."

Range. — Late Oligocene or early Miocene (Japan), middle Miocene (western North America), to Recent. Recent from southern California to Japan, one species ranging through Arctic waters to the north Atlantic. Recent from the intertidal zone to 119 meters (65 fathoms). Occasionally reported deeper.

Original description. — Shell medium to large, trigonal, oblique, usually ventricose; beaks recurved, prosogyrate; position of the umbones varying with age but usually at two-thirds the distance between posterior and anterior ends of the shell; dorsal margin very broadly arched, sloping downward at an angle of about 25°, ventral and anterior margins broadly rounded; epidermis closely adherent, brownish; sculpture of 28 to 55 rounded radial ribs and concentric growth lines which may cross the ribs as conspicuous loops, never as spines; lunule when present circumscribed, never impressed; escutcheon inconspicuous; ligament in dorsal view long, narrow, and oval. Interior porcellaneous, ventral and anterior margins crenulate;

hinge arched; cardinals in each valve slightly nearer anterior margins crenulate; hinge arched; cardinals in each valve slightly nearer anterior than posterior laterals; anterior, also recurved; ligament not elevated on a short, shelly platform; beaks originating at a point slightly anterior to the anterior cardinals; muscle scars large; pallial line simple. Specimens range in length up to about 120 mm. (Keen.)

Remarks. — This genus includes thirteen species and subspecies from the late Cenozoic of western North America and about fifteen species from Japan and Sakhalin Island. One species is here recorded from the San Diego Formation for the first time. This is essentially a northern group of cockles. The type species has been recorded from beds of Pleistocene age as far south as San Quintín, Lower California, Mexico. Beal (833) mentioned "*Cardium* aff. *C. meekianum* Gabb" from much farther south, from beds of late Miocene age near Bahia de Magdalena.

Clinocardium differs from *Cerastoderma* Poli in Mörch (834), from the eastern Atlantic, in the strongly prosogyrate beaks, more numerous ribs, long, low ligament and arched hinge line. The prosogyrate beaks, coarse ribbing as well as the longer and lower ligament are features separating *Clinocardium* from *Laevicardium* Swainson (835).

The west American species of *Clinocardium* were discussed by Keen (836) and those of Japan by Hirayama (837).

Clinocardium nuttallii Conrad
Plate 46, Figure 21

Cochlea corbis Martyn (of west American authors), Univ. Conch., Vol. 2, fig. 80, 1788 [Martyn's work was ruled unacceptable for nomenclature by the Internatl. Comm. Zool. Nomencl.,Opinion 456, March 15, 1957.] — Chenu, Bibl. Conchyl., Première Sér., Vol. 2, p. 25, pl. 28, fig. 2, 1845. "Pulo-Condore."

C[ardium]. nuttalli Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 229, pl. 17, fig. 3, 1837.

Cardium corbis Martyn, Weymouth, Calif. State Fish Game Comm., Fish Bull. No. 4, p. 28, pl. 5, fig. 2, 1920. Gulf of Georgia, British Columbia, to San Diego, California, Recent. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 142, pl. 34, figs. 1a, 1b, 1924 (under subgenus *Cerastoderma*). Various localities cited.

Laevicardium (Cerastoderma) corbis Martyn, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 307, pl. 19, figs. 14, 17, 1931. Various localities; late Miocene to Recent.

Clinocardium nuttalii Conrad, Fitch, State Calif. Dept. Fish Game, Mar. Fish Branch, Fish Bull. No. 90, p. 57 fig. 23, 1953. Bering Sea to San Diego, California. Recent. — Addicott, U. S. G. S., Prof. Paper 523-C, p. C-4, pl. 3, fig. 1, 1966. Half a mile east-northeast of Año Nuevo, San Mateo Co., California. Pleistocene.

Type specimen. — One pair, No. 54036, Academy of Natural Sciences of Philadelphia (A. M. Keen, Veliger, Vol. 8, No. 3, p. 169, 1966).

Type locality. — "Inhabits muddy salt marshes, a few miles from the estuary of the Columbia River."

Range. — "aff." Middle Miocene (838); late Miocene (C. E. Weaver); Pliocene to Recent. Recent from Kamtschatka to San Diego, California, from low tide to 55 meters (30 fathoms). Reported from Miocene to Recent in Japan.

Occurrence in San Diego Fm. — L.A.M. 107, 305, A-1323.

Original description. — Shell ovate-triangular, ventricose, thick; ribs thirty-four, regularly rounded, with prominent arched striae; umbo narrowed; summit very prominent; posterior slope much depressed; posterior margin straight, oblique, simply undulate; ligament margin declining; basal margin regularly arcuate; colour white; epidermis yellowish brown; lateral teeth thick and prominent; margin profoundly serrate. Height, three and a half inches. (Conrad.)

Remarks. — One specimen from Loc. 107 (LAM) partly decorticated, is 70.5 mm long and 84 mm high (beaks lacking) and has about 34 to 35 radial ribs. The shape and shell characters are those of *Clinocardium nuttallii* Conrad. This identification was confirmed by Dr. A. M. Keen who has made a special study of the Cardiidae. Two other casts and one incomplete specimen with portions of the shell, referable to this species, were collected at the same locality.

Two casts of valves in the collection of the Los Angeles County Museum were collected in Fossil Canyon near Chula Vista, the large one is approximately 80 mm long and 86 mm high. The shape and such traces of shell as remain agree with *C. nuttallii.* A right valve from Loc. 305 (LAM), about 43 mm long, the ribs nearly eroded, appears to be referable to this species.

Fraser (839) discussed the ecology of *C. nuttallii.* He found that most of the specimens were about four years old but that it may attain an age of seven years. He also pointed out that in the early stages of growth the length is greater than the height but after the first winter the height exceeds the length and this difference increases with age. This ratio of length to height may vary because a huge specimen from Atka Island, Alaska, mentioned by Keen (840) was 145 mm long, 138 mm high and the convexity 102 mm.

Mitchell (841) made a study of the microscopic structure of the shell and ligament and Taylor (842) discussed the effect of temperature on the growth of this species.

Clinocardium nuttallii differs from the well known Pliocene species, *C. meekianum* Gabb (843), in the less oblique outline, less abrupt posterior truncation and in the more numerous, narrower radial ribs (about 34 rather than about 28) which continue on over the posterior truncation.

A subspecies, *Clinocardium meekianum myrae* (844), from the Etchegoin Formation, with 28 to 30 ribs, was described recently by Adegoke.

This is the first record of *Clinocardium nuttallii* in the San Diego Formation, but it has been recorded from beds of similar age along the Pacific coast from California to Alaska. It has been reported from beds of Pleistocene age as far south as San Quintín, Lower California.

Slodkewitsch (845) reported this species from beds of late Tertiary age in Kamchatka and on Sakhalin Island and it also has been reported ranging from Miocene to

Recent in Japan (846).

Clinocardium nomurai Hayasaka (847) bears a general resemblance to *C. nuttallii* but it has only about 20 radial ribs and a smaller apical angle.

Clinocardium shinjiense Yokoyama (848) described from strata of late Tertiary age in Japan, with about the same number of ribs, has been confused with *C. nuttallii* but the sharp angular ribs are quite different and more closely resemble those of *C. ciliatum* Fabricius.

Fraser mentioned that *C. nuttallii* prefers a somewhat uniform sandy bottom or, if gravelly, confined to patches where the gravel is fairly uniform in size.

GENUS *NEMOCARDIUM* MEEK

Nemocardium Meek, Rept. U. S. Geol. Surv. Terr., Vol. 9, p. 167, 1876. *Cardium semiasperum* Deshayes cited. — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 273, 1931. Type (monotypy): *Cardium semi-asperum* Deshayes. — Tremlett, Proc. Malacol. Soc. London, Vol. 28, Pts. 4 & 5, p. 115, 1950 "Type-species. — *Cardium semiasperum* Deshayes." — Keen, Bull. Amer. Paleo., Vol. 35, No. 153, p. 9, 1954. Type as designated by Sacco.

Type species (by monotypy.) Also designated by Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 27, p. 56, 1899). — "tipo *N. semiasperum* (Desh.)" [*Cardium semiasperum* Deshayes, Anim. s. Vert. Bassin Paris, Vol. 1, p. 573, pl. 55, figs. 1, 2, 1860. "Localities: Aizy, Vregny, Laon." "Gisement: Sables inférieurs." France, Eocene. — Tremlett, Proc. Malacol. Soc. London, Vol. 28, Pts. 4 & 5, p. 121, pl. 16, figs. 9a, 9b, 1950. Hampshire Basin. London Clay, Eocene.]

Range. — Late Cretaceous to Recent. Recent from 18 to 200 meters (10 to 109 fathoms).

Original description. — Shell closely resembling the typical forms of *Protocardia*, but thinner, with two-thirds to three-fourths of surface in front of the stronger posterior, usually echinate, radiating costae, occupied by fine, crowded, radiating striae, and the free margins crenate within all around; cardinal and lateral teeth generally rather slender; pallial line faintly sinuous, irregularly serrated, or nearly simple behind. (Meek, 1876.)

The cardinal teeth in the hinge of this genus are very unequal in size.

Remarks. — *Nemocardium* is represented by a number of species throughout its geologic range, the greatest number of which occur in strata of Eocene age as indicated by Keen (849) in a discussion of this genus. In Europe *Nemocardium s. s.* is reported to range from Cretaceous to Miocene. In England it ranges from Cretaceous to Oligocene (Headon beds (see Tremlett)). According to Finlay and Marwick (850), large forms of *Nemocardium* appeared in New Zealand first in the Kaiatan Stage, early Oligocene, and made their last appearance in the Awamoan Stage, middle Miocene. Later, Keen (1950, p. 25) reported the occurrence of one species of this genus in the Eocene of Australasia. In western North America *Nemocardium s. s.* ranges from late Cretaceous to middle Oligocene. The last representative in this region, so far as known, is *Cardium weaveri* Anderson and Martin (851) described from the Oligocene of Oregon. Recently, Hickman (852) described *Nemocardium (Nemocardium) formosum* from strata in western Oregon assigned Oligocene age. Five Cenozoic species from the North American-northeast Asia region were referred by Keen [1954, p. 316 (10)] to *Nemocardium s. s.* In Japan this genus ranges from late Cretaceous to Recent, being represented in Oriental waters at the present time by *Cardium bechei* A. Adams and Reeve (853).

Stewart (854) gave a discussion of the genus *Protocardia* Beyrich, the type of which is *Cardium hillanum* Sowerby, and he pointed out the differences between that genus and *Nemocardium*. The posterior portion of the valves of the genus *Protocardia* is sculptured with radial ribs and the remainder of the valves is sculptured with concentric ribs.

Four rather similar subgenera of *Nemocardium* are separated in the following key which is adapted from Keen, 1954.

Key to Subgenera of *Nemocardium*

A. Posterior ribs decidedly wider and heavier than the others, usually with spines or crests . . . . . *Nemocardium s. s.*

B. Posterior ribs not decidedly wider than the others.

- a. Outline ovate-trigonal; hinge relatively short . . . . *Arctopratulum*
- aa. Outline ovate-trigonal; hinge relatively long and arched
  - b. Concentric lamellae on posterior area only . . . . . *Keenaea*
  - bb. Concentric lamellae present over entire valve . . . . *Pratulum*

SUBGENUS *KEENAEA* HABE

Keenaea Habe, Gen. Jap. Shells. Pelecypoda, No. 2, p. 152, September, 1951. — Keen, Bull. Amer. Paleo., Vol. 35, No. 153, p. 317 (11), 1954. Original designation of type cited.

Type species (by original designation). — "Type species: *Cardium samarangae* Makiyama." [= *Nemocardium samarangae* Makiyama, Mem. Coll. Sci., Kyoto Imper. Univ., Ser. B, Vol. 10, No. 2, art. 6, p. 143, 1934. A new name for *Cardium modestum* A. Adams and Reeve, Zool. Voy. Samarang, Moll., Pt. 3, p. 77, pl. 22, fig. 6, 1848 (issued 1850). "Hab. Eastern Seas." (Not *Cardium modestum* Philippi, 1849; not *Cardium modestum* Conrad, 1855). Also illustrated by Habe, 1951, fig. 326 (p. 147).]

Range. — Late Oligocene to Recent. Japan to Lower California. Recent from 18 to 476 meters (10 to 260 fathoms).

Description. — Smaller than *Nemocardium s. s.*, with secondary concentric lamellae on posterior ribs; the latter not sharply differentiated. Differs from *N.*

(Pratulum) by the presence of the concentric lamellae on ribs and a tendency toward fine beading on ribs of the central part of the disk. (Keen, 1954.)

Remarks. — Several Cenozoic species of the Cardiidae in the north Pacific region have at times been placed in various genera or subgenera such as *Protocardia* Beyrich, *Nemocardium* Meek, and *Pratulum* Iredale. Establishment of *Keenaea* as a subgenus for these species appears justified because of differences in the sculpture and hinges of these forms in comparison with the type species of other supraspecific units of the Cardiidae. Five Cenozoic species in the north and northeastern Pacific regions have been assigned (one tentatively) by Keen to the present subgenus.

Nemocardium (Keenaea) centifilosum Carpenter
Plate 46, Figures 4, 5, 10, 15

Cardium (?modestum, var.) *centifilosum* Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 611, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 97, 1872. — Carpenter, Proc. Calif. Acad. Nat. Sci., Vol. 3, p. 209, February, 1866. "Monterey, 20 fms. alive; Santa Barbara I, Catalina Island, 40 fms. Cooper."

Cardium var. *centifilosum* Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 642, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 128, 1872.

Cardium centifilosum Carpenter, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 297, 1874. "Well at San Diego." "Pliocene." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. San Diego well. — Cooper, Calif. State Min. Bur., Seventh Ann. Rept. Calif. State Mineral. p. 232, 1888. "Pl. — San Diego well." — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, August, 1889. Dall's record (1874) cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited from San Diego well. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) cited. Referred to *Nemocardium centifilosum* Carpenter.

Protocardia centifilosa Carpenter, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 142, 1903. "San Diego well (Dall)." "Pliocene." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 146, pl. 34, figs. 2a, 2b, 2c, 2d, 1924. Recent. Also cited from "San Diego." "Pliocene." — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 84, 1929. "San Diego Pliocene."

Cardium (Protocardia) centifilosum Carpenter, Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 267, pl. 20, figs. 2a, 2b, 2c, 2d, 1918. "Vicinity of the Farallon Islands in 40 to 46 fathoms."

Nemocardium (Keenaea) centifilosum Carpenter, K. V. W. Palmer, Geol. Soc. America, Mem. 76, pl. 91, pl. 10, figs. 7-11, 1958. (Holotype illustrated.)

Type specimen. — No. 15262, United States National Museum.

Type locality. — "Cat. Is., 30 — 40 fm." Carpenter, (1864, p. 611.) [Catalina Island, California. See K. V. W. Palmer, 1958, p. 92.]

Range. — Late Miocene (856) to Recent. Recent from the Farallon Islands, California, to Point Abreojos, Lower California, Mexico, in 18 to 137 meters (10 to 75 fathoms).

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 1404, 12078, 28893. L.A.M. 107, 305A. S.D. 75, 294.

Original description. — "Probably = *modestum*, Ad. & Rve.; but rounder, ribs sharper and more distant."

Supplementary description. — C. T. parva, tenuissimâ, inflatâ, subquadratim rotundatâ; umbonis angustis, tumidioribus; marginibus, dorsalibus subalatis, antico et ventrali aequaliter rotundatis, postico vix truncato, totâ superficie, (nisi umbonibus et dorsum versus utroque latere laevigus,) tenue liratâ; liris circ. centum, quoad magnitudinem extantibus, angustis; interstitiis sub-equalibus, subquadratis, interdum punctato-decussatis; parte posticâ à lineâ definita, lirulis minus conspicuis, laminis concentricis extantibus, crebrioribus eleganter exasperata; intus, dent. card. validioribus, lat. subdistantibus; cic. adduct. ovalibus, haud impressis.

Long. 0.51, lat. 0.48, alt. 0.34. (Carpenter, 1866.)

Remarks. — The radial ribs on the posterior third of the shell of this species separated from the anterior series by a slight carina, are crossed by raised concentric lamellae.

A considerable number of specimens of *Nemocardium centifilosum* in various stages of preservation, are present in the collections from the San Diego Formation. These vary in size, many of those from Loc. 1404(CAS), corner of India and Upas streets, are about 16 mm high; one of the largest ones is 18.8 mm high. A single left valve in the Hemphill collection from the San Diego well is approximately 16.4 mm long and 16.1 mm high. The largest specimen from Loc. 107 (LAM), end of Arroyo Drive, is a cast 19.8 mm long and 19 mm high. An impression of a right valve collected by Charles Sternberg on Reynard Way off State Street, is 22 mm long. One of the largest Recent specimens of *N. centifilosum* in the collections of the California Academy of Sciences from Cortez Bank off southern California, in 73 to 110 meters (40 to 60 fathoms), is 16.8 mm long and 16 mm high, convexity (both valves together), 11 mm. The fossil specimens agree in all observable characters with those of the Recent species.

A cast of both valves of a specimen from Loc. 107 (LAM), has the general shape of *Nemocardium* but it is much larger than any specimens of *N. centifilosum* which we have observed. It is 33.8 mm long, 33 mm high, the convexity (both valves together), approximately 27.3 mm. The shell material is lacking and no opinion is here ventured concerning the species represented by this cast.

A form described as *Cardium richardsoni* by Whiteaves (857) is now generally considered to be only a northern variety of *Nemocardium centifilosum*, ranging from Forrester Island, Alaska, to San Francisco, California. Dall (858) stated concerning this form, "The northern specimens forming the variety are a little stronger and coarser than those from California, with which they seem to be united by intermediate gradations, though the extremes have apparently good distinctions." However, as mentioned by Willett (859), and by Woodring, Bramlette, and Kew (860), the only difference between the northern and southern forms is in size. We have examined specimens collected by George Willett at Forrester Island,

Alaska, the largest of which is 21.6 mm long, 19.6 mm high, convexity (both valves together), 15.1 mm. Woodring, Bramlette, and Kew, reported large shells from Alaska which are 26.2 mm long and mentioned that the largest one from off Cortez Bank in the United States National Museum, is 19.6 mm long. A fossil valve which they illustrated from beds of Pleistocene age from San Pedro, California, is 24.9 mm long and 22.8 mm high and thus comparable in size to the northern form *N. centifilosum richardsoni.*

SUPERFAMILY VENERACEA RAFINESQUE (861)
FAMILY VENERIDAE RAFINESQUE (862)

Shell equivalve, porcelaneous, beaks prosogyrous, smooth or variously sculptured (predominantly concentric), lunule and escutcheon usually well defined, resilium external, margins crenulated or smooth; pallial sinus varying in different genera, often deeply sinuated; hinge with teeth radially arranged, one or more of the cardinals often bifid or grooved, right middle and left posterior ones usually thicker than right and left anterior teeth, a left anterior lateral may be well developed or lacking, posterior laterals usually small or lacking. Often burrowing just beneath surface of sea bottom. Jurassic to Recent.

Remarks. — This family, which has reached its greatest development and diversification at the present time, contains many genera for which scores of names (see Frizzell, 1930) have been proposed.

Several authors have given special attention to this family among which are Dall (863), Jukes-Browne (864), Marwick (865), Palmer (866), Frizzell (867), Casey (868), and Keen (869). References to earlier works on this family can be found in those papers. A study of the Veneracean group led Casey to conclude (p. 158), "the author is convinced that the genera at present grouped in the family Veneridae (the superfamily Veneracea of Frizzell, 1936) are a polyphyletic assemblage of forms derived from various cyprinid and noncyprinid sources." However, he believed it best to leave undisturbed the systematic homogeneity of this well known family until evidence of a phylogenetic classification had been presented.

Recent tropical and subtropical west American species of the Veneridae were discussed by Hertlein and Strong (870), by Keen (871), and by Olsson (872).

Ansell (873) discussed the functional morphology of the British species of Veneracea.

GENUS *DOSINIA* SCOPOLI

Dosinia Scopoli, Introductio ad historiam naturalem, p. 399, 1777. Reference to: "*Cricompholos* Klein. Chama Dosin. Adans." — Hertlein and Strong, Bull.

Key To Genera Of Veneridae (874)

A. Left valve with an anterior lateral tooth or denticle.

a. Shell orbicular, large, polished . . . . . *Dosinia*

aa. Shell trigonal or elongated.

b. Shell trigonal, beaks subcentral . . . . . *Tivela*

bb. Shell longer than high; beaks anterior to midline.

c. Inner ventral margin obliquely grooved; not exceeding 35 mm in length . . . . . *Transennella*

cc. Inner ventral margin not grooved

d. Exterior of valves with coarse concentric sculpture . . . *Saxidomus*

dd. Exterior of valves smooth or with fine concentric sculpture

e. Pedal retractor impression deeply excavated; shell larger rather thick . . . . . *Megapitaria*

ee. Pedal retractor impression not deeply excavated; shell rather thin . . . . . *Pitar*

B. Left valve lacking an anterior lateral tooth or denticle

a. Exterior of valves smooth or with fine concentric sculpture

b. Shell obliquely elliptical, medium-sized to large; pallial sinus narrow . . . . *Compsomyax*

bb. Shell trigonal, not exceeding 8 mm in length; pallial sinus wide . . . . . *Psephidia*

aa. Exterior of valves with concentric and radial (always on beaks) sculpture

c. Escutcheon present on one or both valves

d. Left posterior cardinal elongated; middle cardinal thick; hinge plate triangular; pallial sinus short . . . . . *Chione*

dd. Left posterior cardinal short; middle cardinal not thickened, bifid; hinge plate narrow and long; pallial sinus long . . . . . *Protothaca*

cc. Escutcheon lacking . . . . . *Irusella*

Amer. Mus. Nat. Hist., Vol. 107, Art. 2, p. 188, 1956. Type (by monotypy): Chama Dosin Adanson.

Dosinidia Dall., Proc. U. S. Nat. Mus., Vol. 26, No. 1312, p. 437, December 29, 1902. "Type, *Venus concentrica* Born." [Rer. Nat. Mus. Caesarei Vindobonensis, Pars 1, Testacea, p. 58, 1778. (No locality cited. Ref. to "List Hist. Conch. 1, 3, f. 99, 102, 104."; "Petiv. Gaz. t. 16, f. 1, t. 93, f. 15, 18."); Test. Mus. Caesar. Vindobonensis, p. 71, pl. 5, 1780. "Habitat ad insulam Maurittii & Jamaicam, Lister."]

Type of genus (by monotypy): Chama Dosin Adanson, Hist. Nat. du Sénégal, p. 225, pl. 16, fig. 5, 1757. "On la voit assez abondamment sur la côte de Portudal." See Fischer-Piette et al., Jour. de Conchyl., Vol. 85, No. 4, p. 308, pl. 14, fig. 4, 1942 [A *Dosinia (Dosinia) concentrica*]. Also illustrated by Palmer, Palaeontogr. Americana, Vol. 1, No. 5, p. 278, pl. 49, figs. 2, 5, 10; pl. 51, fig. 4, 1927-1929. Pleistocene and Recent.

Range. — Eocene to Recent in New Zealand (Marwick); Oligocene (876) to Recent in western North America. Recent mostly in shallow tropical and subtropical waters to a depth of 120 meters (66 fathoms).

Description. — Shell orbicular, rather thick, valves moderately inflated, posterior dorsal margin usually very gently rounded and lending a flattened appearance; lunule well defined, escutcheon, if present, narrow, lacking in *Dosinia s.s.*; sculpture of fine, incised concentric grooves; hinge of left valve with 3 cardinals, ligament rather long, more or less sunken; pallial sinus usually ascending, pointed at the end; margins of valves smooth.

Remarks. — A discussion concerning the identification of the type species of this genus has been given by Fischer-Piette et al. and reviewed by Hertlein and Strong. It appears that Adanson's species "Chama Dosin" is identical with *Venus concentrica* Born. The subgenus *Dosinidia* Dall is thus a synonym of *Dosinia s. s.*

The tropical and subtropical genus *Dosinia* is represented in Neogene strata of western North America by several species. It ranged north to western Washington during middle Miocene time, but only north to Santa Clara Co. (877), California, in the Pliocene, and to Newport Bay, California, in late Pleistocene time.

One species, or perhaps two, and a subspecies described in the present paper, occur in strata of Pliocene age in southern California but only one occurs in beds of Pleistocene age in that region. Three species occur in the tropical and subtropical waters between Scammon's Lagoon, Lower California, to Punta Peñasco, Mexico, and south to Ecuador and two of them to Paita, Peru. Records of the occurrence of *Dosinia ponderosa* living in the waters of San Diego Bay are believed to have been based upon Pleistocene fossils.

SUBGENUS *DOSINIA* S. S.

Dosinia ponderosa diegoana n. subsp.
Plate 47, Figures 2, 3, 6, 8, 10; Plate 49, Figure 8; Plate 51, Figure 14

Dosinia ponderosa (Gray) variety *jacalitosana* Arnold, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, pp. 353, 912, pl. 15, figs. 2a, 2b, 1931. "*Dosinia* beds of Balboa Park, San Diego (Hertlein and Grant)."

Not *Dosinia jacalitosana* Arnold, 1910.

Dosinia ponderosa (Gray), var., Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, pp. 89, 104, pl. 16, fig. 6; pl. 19, fig. 1; pl. 20, fig. 7, 1950. Careaga Sandstone, Santa Maria district. Also cited from "U. S. Geol. Survey localities 2459, 2662 (Balboa Park)", San Diego.

Dosinia ponderosa Gray, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 38, pl. 17, figs. a, b, 1968. "near the Mexican-United States boundary and one-half a mile from the ocean". Pliocene.

Not *Arthemis ponderosa* Gray, 1838.

Description. — Shell large, elongately orbicular, equivalve, moderately inflated, beaks situated decidedly anterior; lunule large and impressed; anterior margin and ventral margin broadly rounded, posterior dorsal margin gently rounded and merging into the posterior margin which is very broadly rounded and lending a subtruncated appearance; surface sculptured with concentric incremental lines; hinge similar to that of *Dosinia ponderosa* but the ventral margin of the hinge plate is more arcuate and the anterior lateral tooth of the left valve is separated by a greater distance from the anterior cardinal. Length, 121 mm, height, 130 mm, convexity (both valves together, gaping 13 mm along ventral margin), 63 mm.

Type specimen. — Holotype (and paratypes) in the California Academy of Sciences, Department of Geology, Type Collection; paratypes in the San Diego Society of Natural History and in the Los Angeles County Musuem, Invertebrate Paleontology Collection.

Type locality. — *Dosinia* beds in Balboa Park, on point between Cabrillo Canyon and a gulch, about 100 meters south of the west end of Laurel Street Bridge over Cabrillo Canyon, San Diego.

Range. — Middle Pliocene, San Diego Formation at San Diego, and in the Careaga Formation in the Santa Maria district, California.

Occurrence in San Diego Fm. — C.A.S. 1181, 1401, 1402, 1415, 36384. L.A.M. P.87, 104, 107, 127, 180, 305, 305A, 319. S.D. 29, 80, 408, 417, 05252. U.C. A-8333. U.C.L.A. 312, 1386, 2359.

Remarks. — *Dosinia ponderosa diegoana*, new subspecies, differs from *Dosinia ponderosa* in that the outline is more elongated (dorsal to ventral), the beaks are more anteriorly situated, the lunule is shallower, the posterior dorsal margin is less projecting, lending a subtruncated appearance to the posterior portion of the shell, the ventral margin of the hinge plate is more arcuate, and the anterior lateral of the left valve is separated from the anterior cardinal by a correspondingly greater space.

This subspecies appears to be intermediate in shell characters between *Dosinia ponderosa* (878) and *Dosinia jacalitosana* Arnold (879). Some specimens from Balboa Park are nearly as elongate in outline as *D. jacalitosana* but on most specimens the posterior dorsal margin is more acutely rounded than that of *D. jacalitosana*. The hinge of the type of the latter has not been described, but Nomland (880) illustrated the hinge of a right valve attributed to Arnold's species. The results of a study of a series of specimens from the San Diego Formation lead us to describe this form as a subspecies of *D. ponderosa* rather than to identify it with *D. jacalitosana* or with either of the forms of late Miocene age placed in the synonymy of that species by Grant and Gale.

Woodring pointed out that the form which he illustrated from the Careaga Sandstone in the Santa Maria district is identical with the *Dosinia* occurring in Balboa Park in San Diego.

The elongated form, very anteriorly placed beaks and subtruncated posterior end are features easily separating this new subspecies from *Dosinia arnoldi* Clark and *D. merriami* Clark from beds of late Miocene age in California.

GENUS *TIVELA* LINK

Tivela Link, Beschreib. Naturalien-Sammlung Rostock, Pt. 2, p. 152, 1807. Species cited: "*Tivela vulgaris.*" "*Venus corbicula.* L. G. p. 3278" in synon.: and "*Tivela tripla.*" "*V. tripla.* L. G. p. 3276" in synon. — Nickles Moll. Test. Marins Cote Occid. d'Afrique, Man. Ouest-Africain, Vol. 2, p. 199, 1950.

Type species (designated by Kobelt, Illustr. Conchylienbuch, Bd. 2, Lief, 10-11, p. 334, 1881). — "Typus ist *Cytherea tripla* Linné (Taf. 97 Fig. 12) von der Westafrikanischen Küste." [Also illustrated by Römer, Monogr. Molluskengattung *Venus*, Linné (Cassel), Bd. 1, p. 20, pl. 7 figs. 2, 2a-c, 1861. West Africa. — Nicklés, 1950, p. 199, fig. 378. For a discussion of this species see Dodge, H., Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 122-123, 1952.]

Range. — Eocene to Recent (*Tivela s. s.*, Miocene to Recent). Recent from the intertidal zone to 73 meters (40 fathoms).

Description. — Shell trigonal, smooth, medium size; external ligament short in the typical species; hinge with three cardinal teeth in each valve and an anterior lateral in the left valve; inner margins smooth; pallial sinus deep, rounded at the end.

Remarks. — The type species is a highly trigonal shell about 20-35 mm in altitude. The anterior and posterior areas are flattened and a lunular area is delimited by a fine thread. The external ligamental area is comparatively small. The pallial sinus extends anteriorly to about two-thirds the distance from the posterior margin.

The general characters of the type species differ so much from those of the huge coarse shells of west American species usually referred to *Tivela* that it seems desirable to place the California species in the subgenus *Pachydesma* Conrad.

Dodge considered Herrmannsen's designation of the type of *Tivela* to be equivocal. There may be an element of doubt concerning the validity of that designation but there is no question concerning the validity of the designation of the same species by Kobelt.

SUBGENUS *PACHYDESMA* CONRAD

Trigonella Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 253, 1837.

Sole species, *Cytherea crassatelloides* Conrad. Not *Trigonella* Da Costa, 1778, nor *Trigonella* Hehl, 1842.

Pachydesma Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 7, p. 31, March 1854. New name for *Trigonella* Conrad, 1837, not of Da Costa, 1778, nor of Hehl, 1842. "This name being superseded, I propose to substitute that of *Pachydesma*". — Olsson, Mollusks of the Tropical EasternPacific (Paleo. Res. Inst.: Ithaca, New York), p. 266, 1961. Type species, *Donax stultorum* Mawe.

Type species (by monotypy). — *Cytherea crassatelloides* Conrad.

Range. — Eocene to Recent. Recent from the intertidal zone to about 24 meters (13 fathoms).

Description. — Shell large, thick, trigonally elongate, porcelaneous, beaks prominent, lunule not defined; distinct setting off of the left cardinal from the nymph; three cardinal teeth in each valve (sometimes with accessories), a large anterior lateral tooth in the left valve and two lateral lamellae in the right valve.

Remarks. — The recorded occurrence of species of *Pachydesma* in California in beds as early as those of Eocene age suggests the possibility that this subgenus originated in west American waters.

Tivela (Pachydesma) stultorum Mawe
Plate 50, Figures 4, 5, 6

Donax stultorum Mawe, Linn. Syst. Conch., pp. 37, 40, pl. 9, fig. 7,1823. [No description.]

C[ytherea]. crassatelloides Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 253, pl. 19, fig. 17, 1837 (under subgenus *Trigonella*).

Cytherea (Tivela) crassatelloides Conrad, Stearns, Proc. U. S. Nat. Mus., Vol. 21, No. 1149, pp. 371-378, pls. 23-25, 1898. Santa Cruz, California, to Ballenas Bay, Lower California.

Tivela stultorum Mawe, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 340, pl. 19, fig. 8, 1931. (Reproduction of Mawe's original figure.) [Not figs. 3a, 3b? = *Tivela scarificata* Berry.] Pliocene to Recent.

Type specimen. — Location unknown to the present authors. Type specimen of *Cytherea crassatelloides* Conrad, one pair No. 53900, Academy of Natural Sciences of Philadelphia (A. M. Keen, Veliger, Vol. 8, No. 3, p. 169, 1966).

Type locality. — "Indian Seas." [Original locality believed to be erroneous. The type locality of *Cytherea (Trigonella) crassatelloides* Conrad, generally considered to be identical with *Donax stultorum* Mawe, is, "Inhabits the coast of California about a foot deep in the sand — abundant round Sta. Diego as well as near Sta. Barbara."]

Range. — Middle Pliocene to Recent. Recent from Stinson Beach, Marin Co., California (881), to Magdalena Bay, Lower California, Mexico, from the intertidal zone to a depth of 24 meters (80 feet), living at a depth of about 150 mm (6 inches), on a clean sandy beach where there is a heavy surf.

Occurrence in San Diego Fm. — L.A.M. 305, 305C, 319, A-1323. U.C.L.A. 294, 305, 312, 1383.

Original description of *Cytherea crassatelloides.* — Shell equilateral, triangular, thick; convex-depressed; lunule undefined; posterior extremity truncated; ligament short, very broad and elevated; apex very prominent; beaks not oblique; colour whitish, frequently rayed with brown; cardinal teeth very thick and prominent; anterior tooth elongated, thick; sinus of palleal impression angular. Length, seven inches. (Conrad.)

Remarks. — Several single valves of this species are present in the collections of the University of California at Los Angeles. The largest specimen, a right valve, is 78.8 mm long, 62.2 mm high, the convexity, 15.4 mm. This is small in comparison to a Recent specimen collected by Mr. John Strohbeen which is 162 mm long, 131 mm high, the convexity (both valves together), 77.5 mm. Fitch (882) mentioned a specimen which was 187 mm long.

Two single valves and some fragments of this species are present in the collections of the Los Angeles County Museum. A fragment of a left valve from Loc. 305 (LAM), from near the Mexican boundary, is 10 mm thick.

The present record of this species in the San Diego Formation is the first unless the equivocal record of Orcutt (883) refers to specimens of Pliocene age. He cited it from Tertiary beds at Pacific Beach. This species has been recorded from other localities in California in strata of Pliocene age in the San Benito quad., in the Santa Maria district, in Los Angeles, and in the Merced Formation in northern California.

There have been differences of opinion as to the correct name for this species. Certainly Conrad's *Cytherea crassatelloides* from southern California is referable to this species. However, most authors in modern times have accepted *Donax stultorum* Mawe as representing this species. The locality "Indian Seas" given by Mawe for this species is generally believed to be an error. The only modern record we have noticed of the identification of *Tivela stultorum* in oriental waters is that in a list of shells from Hongkong, mentioned by Campbell (884) who attributed the identification to H. A. Pilsbry. That list contains such American species as *Pecten circularis* Sowerby, *Olivella biplicata* Sowerby, *Busycon perversa* Linnaeus, and *Olivella sayana* Ravenel, and cannot be considered as an authoritative locality record for Mawe's species.

Woodring (885) considered the assignment of *Donax stultorum* to west American waters a very doubtful procedure and preferred retention of the name *Tivela crassatelloides* for the west American species.

Cytherea virginea A. Adams and Reeve was described with the locality "Eastern Seas." Tomlin examined the type specimen and concluded that it is identical with the California species which he cited as *Tivela stultorum.* This conclusion was affirmed by the French authors Fischer and Fischer-Piette. Evidence supporting the opinions of those authors is that several species recorded from oriental waters by A. Adams and Reeve are now known to be west American species. Among these are "*Artemis*" *dunkeri* Philippi, "*Mactra*" *thracioides* A. Adams and Reeve, "*Lucina*" *sericata* Reeve, and *Conus borneensis* A. Adams and Reeve (now believed to be identical with *Conus arcuatus* Broderip).

The present authors feel that the use of *Tivela stultorum* for a west American species is justified unless definite proof is forthcoming that the name is applicable to an oriental species.

Tivela scarificata Berry (886) which occurs in beds of Pleistocene age in southern California differs from *T. stultorum* in the more elongate shape and in the presence of scar-like markings on the interior.

An interesting form generally considered to be referable to *Tivela stultorum* has been discussed by Fitch (887). He pointed out that individuals of this species living in sand along with numerous specimens of *Donax gouldii* develop an elongate shape and often reveal the presence of an area of irregular zone of growth just anterior to the posterior umbonal margin. This irregular growth is believed to be the result of injury to the corresponding portion of the mantle caused by pinching by the valves of *Donax gouldii.* One of the fossils in the present collection shows a similar zone of irregular growth.

Two excellent papers dealing with *Tivela stultorum* in present day waters are by Weymouth (888) and Fitch (889). Young shells are said to possess a byssus which later becomes obsolete.

[GENUS *PITAR* RÖMER]

Pitar Römer, Kritische Untersuchung der Arten des Molluskengeschlechts *Venus* bei Linné und Gmelin mit Berücksichtigung der später beschriebeben Arten (Cassel), p. 15, 1857. Sole species, "*C. tumens* Gmel." — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 232, 1930. Monotype species *Venus tumens* Gmelin.

Caryatis Römer, Malakozool. Blätter, Bd. 9, pp. 58, 60, March, 1862. Species cited: *Cytherea tumens* Gmelin, *Cytherea striata* Sowerby, and others. — Stoliczka, Mem. Geol. Surv. India, Palaeo. Indica, Ser. 6, Vol. 3 pp. XVIII, 151, 1871. "*Venus tumens*, Gmelin, is the type of this very well marked form of *Cytherea.*" Not *Caryatis* Hübner, 1816. Lepidoptera.

Pitaria Romer (emended), Dall, Proc. U. S. Nat. Mus., Vol. 26, No. 1312, p. 353, December 29, 1902. "Type *Venus tumens* Gmelin."

Type species (by monotypy): "*C. tumens* Gmel. (le Pitar Adans.)" [= *Cytherea tumens* Gmelin, Linn. Syst. Nat., ed. 13, p. 3292, 1791. "Habitat ad Africa littus occidentale." Ref. to Adanson, Hist. Nat. du Sénégal, pl. 16, fig. 7, 1857. Locality, p. 226, "Elle est également répandue sur toute la côte sablonneuse depuis le cap Verd jusqu'au fleuve Gambie." See also P. -H. Fischer et al., Jour. de Conchyl., Vol. 85, No. 4, p. 316, pl. 14, fig. 6, 1942. Also illustrated by Römer, Monogr. Molluskengattung *Venus*, Linné, Bd. 1, p. 81, pl. 22, figs. 1, 1a, 1b, 1c, 1869. "Mare Senegalense et Guineense; (Bathhurst in ins. Stae Mariae)." Also illustrated by Tegland, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 10, p. 277, pl. 21, figs. 1-3, 1929 (as *Pitaria (Pitaria) tumens*].

Range. — Eocene to Recent. Recent chiefly in tropical and subtropical waters, a few species in warm waters, from the intertidal zone to 540 meters (295 fathoms).

Description. — Shell medium-sized, trigonal-ovate, strongly inflated; lunule wide, limited by a slightly depressed groove; escutcheon indistinct; sculpture consisting of incrementals; hinge of right valve consisting of 2 indistinct anterior lateral lamellae flanking a deep socket, and 3 cardinals, the anterior (3a) and middle (1) ones almost perpendicular to hinge-margin, the middle one heavy, the posterior one (3b) bifid; hinge of left valve consisting of a heavy anterior lateral and 3 cardinals, the anterior one (2a) resembling the right anterior cardinal (3a), the middle one (2b) very heavy and obscurely bifid, the posterior one (4b) slender and partly joined to the nymph; pallial sinus deep, its apex acutely angular.

(Woodring, W. P., Carnegie Inst. Washington, Publ. 366, p. 152, 1925.)

Remarks. — This genus is represented in the Cenozoic of western North America by a number of species. About 18 or 20 species and subspecies have been recorded as occurring in the Cenozoic of California and additional species occur in the Tertiary strata of Oregon, Washington, Alaska, and elsewhere.

Some authors have used Dall's emendation of the genus name, *Pitaria*, but as mentioned by Iredale, 1924, and Stewart, 1930, there appears to be no justification for this. *Pitar*, according to authorities on the classical languages is correct as it stands. In the Sanscrit language *Pitar* means father, according to Baugh (890). It is interesting to note that the word "*Pitar*" also was used by natives in the western Pacific (891).

Katherinella Tegland, (892), described as a subgenus of *Pitar*, with the type *Pitaria arnoldi* Weaver, differs from typical *Pitar* in that the anterior lateral of the left valve is small and extends from near the lower margin of the hinge plate upward nearly to the junction of the cardinals. The shell is thin and the valves are only moderately inflated. This subgenus is known to occur only in beds assigned to late Oligocene age, and to middle Miocene age, in Oregon, Washington, and Alaska.

Pitar is represented in the late Pliocene and Quaternary in southern California by two species. Fourteen species and subspecies were cited by Hertlein and Strong as occurring in tropical and subtropical west American waters and Olsson has added three more from northern South America.

[*Pitar newcombianus* Gabb]

C[irce]. L[ioconcha]. newcombiana Gabb, Proc. Calif. Acad. Nat. Sci., Vol. 3, p. 189, January, 1865.

[?]"*Callista* sp. indet." Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 296, 1874. Well at San Diego. — Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 85, August, 1889. Dall's record cited. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919.

Callista newcombiana Gabb, Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 231, 1888. "Pl. — San Diego well." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 144, 1903. "Pliocene. — San Diego well (Cooper)."

Pitaria newcombiana Gabb, I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 151, pl. 57, fig. 2, 1924. "Pliocene at San Diego Well, California."

Pitar newcombianus Gabb, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 345, 1931. "Pliocene; San Diego well, Balboa Park, San Diego (Cooper)."

Type specimen. — Location of type specimen unknown to the present authors.

Type locality. — "Hab. two valves, Catalina Island, 120 fms. Dr. Cooper."

Range. — ? Late Pliocene, southern California, to Recent. Recent from Monterey, California, to Punta Peñasco in the Gulf of California and south to Port Guatulco, and Clarion Island, Mexico.

Occurrence in the San Diego Formation. — Based upon records of Dall and Cooper.

Remarks. — Dall in 1874 mentioned a fossil bivalve occurring in the San Diego well as "*Callista* sp. indet. Smooth, inflated, thin; much like *Callista newcombiana*, erroneously described as *Lioconcha* by Gabb" (893). Cooper in 1888 cited "*Callista newcombiana* Gabb" from the San Diego well, and most subsequent records in the literature appear to be based upon his record. We have not seen specimens of this species from the San Diego Formation, and it has not been reported from strata of Pliocene age in southern California. It may perhaps occur in beds of that age, but for the present we are unable to validate its occurrence at San Diego.

Records of the occurrence of this species in beds of late Miocene age cited by Clark, 1914, and Weaver, 1950, may be based upon some other species.

GENUS *MEGAPITARIA* GRANT AND GALE

Megapitaria Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 346, November 3, 1931. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 272, 1961. Type, by original designation.

Type species (by original designation). — "Type, *Cytherea aurantiaca* Sowerby" [Gen. Rec. and Foss. Shells, Vol. 2, Pt. 33, pl. 196, fig. 3, 1831. (No locality cited.) — Reeve, Conch. Icon., Vol. 14, *Dione*, species 12, pl. 3, fig. 12, 1863 (as *Dione aurantia*). "Hab. Acapulco, South America." — Olsson, 1961, p. 273, pl. 46, figs. 1, 1a, 1c (as *Macrocallista (Megapitaria) aurantiaca*). Lower California to northern Peru].

Range. — Pliocene to Recent. Recent from the intertidal zone to 161 meters (88 fathoms).

Description. — Shells usually large or of moderate size, thick, ovate-subtrigonal, ventricose, smooth, sculptured only with fine lines of growth. Differing from *Pitar s. s.* in the larger, thicker shell and in the deep pedal retractor impression.

Remarks. — Shells of typical *Megapitaria* were referred to *Macrocallista* Meek (894) in the earlier literature. They resemble that genus in general shell characters but the valves are more ovate or circular in shape and are less depressed. They resemble the genus *Pitar* Römer which was described much earlier than *Macrocallista* but they are much larger and thicker. Grant and Gale gave an adequate discussion of *Megapitaria* which they compared with other genera. This genus is based upon a west American species and until the relations of the various supra-specific groups of the Veneridae are more clearly delimited, it seems best to apply *Megapitaria* to shells similar to the type species.

Megapitaria squalida Sowerby

Plate 50, Figures 1-3

Cytherea squalida Sowerby, Proc. Zool. Soc. London for 1835, p. 23, issued April 16, 1835. — Sowerby, Thes. Conch., Vol. 2, *Cytherea*, p. 629, pl. 131, figs. 87, 88, 89, 1851. "California." [Not the record "from the Philippine Islands."]

Dione squalida Sowerby, Reeve, Conch. Icon., Vol. 14, *Dione*, species 10, pl. 3 fig. 10, 1863. "Hab. California". [Not the record "Philippine Islands."]

Pitar (Megapitaria) squalidus Sowerby, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 347, 1931.

Various localities cited, Pliocene to Recent.

Megapitaria squalida Sowerby, Hertlein and Strong, Zoologica, Vol. 33, Pt. 4, p. 168, 1948. "Range: Scammon Lagoon, Lower California, to the Gulf of California and south to Mancora, Peru." — Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 134, fig. 303, 1958. [Same range as in preceding reference.]

Macrocallista (Megapitaria) squalida Sowerby, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 273, pl. 46, figs. 2, 2 a-c, 1961. Lower California to northern Peru.

Type specimen. — British Museum (Natural History).

Type locality. — "Hab. ad Sanctam Elenam." "Found in sandy mud at a depth of six fathoms."

Range. — Middle Pliocene to Recent. Recent from Cedros Island, Lower California, Mexico, to the Gulf of California, and south to Mancora, Peru; on sandy mud flats to a depth of 161 meters (88 fathoms).

Occurrence in San Diego Fm. — L.A.M. 302.

Original description. — Cyth. testâ ovato-subcordatâ, *crassiusculâ*, laevi, pallidè fuscâ, nonnunquam maculis irregularibus saturatioribus; epiderme fuscâ; latere postico longiore, prope partem bentralem subacuminato: long. 2.7, lat. 1.3, Alt. 2. poll. (Sowerby.)

Remarks. — Three valves of this species, the largest, a right valve about 61 mm long, are present in the collections of the Los Angeles County Museum from Loc. 302 (LAM). These fossils agree in all details with Recent specimens of this species. A fragment from Loc. 122, Pacific Beach, may have come from beds of Pleistocene age.

This is the first record of *Megapitaria squalida* from the San Diego Formation. It has been reported with question from Strata of Pliocene age and definitely from beds of Pleistocene age in southern California. It also has been recorded from Pliocene to Recent in Lower California and in Ecuador. Recent specimens 116 mm long have been reported from the Gulf of California.

Megapitaria squalida differs from the similar *M. aurantiaca* Sowerby which lives in the same region, in that the shell is more produced both anteriorly and posteriorly and in that it possesses a shiny purplish-brown or spotted or striped periostracum rather than dull orange brown.

GENUS *COMPSOMYAX* STEWART

Compsomyax Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 224, August 9, 1930. — Grand and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 333, 1931. Type as indicated by Stewart.

Type species (by original designation). — "Type species, *Saxidomus gibbosus* Gabb (= *V. subdiaphana* (Carpenter)." [Geol. Surv. Calif., Palaeo., Vol. 2, p. 58 pl. 16, figs. 18, 18a, 18b, 1869. "Common in the Pliocene of Eagle Prairie, Humboldt County." Also illustrated by Stewart, 1930, pl. 14, fig. 6 (lectotype).]

Range. — Early (895) or middle Miocene (Temblor) to Recent, western North America. Japan, Miocene. Recent from 2 to 548 meters (1 to 300 fathoms).

Original description. — "This species differs from typical *Venerella* in having a strongly bifid posterior right cardinal."

Remarks. — The type species of *Compsomyax* was originally described under the genus *Saxidomus*, later placed in *Marcia* H. and A. Adams, in *Venerella* Cossmann, and finally *Compsomyax* was proposed for it by Stewart. This in turn has been cited as a subgenus of *Venerella* and *Katherinella* and in some cases has received the rank of genus.

The hinge of *Compsomyax* lacks an anterior lateral tooth in the left valve which separates it from *Pitar* Römer and *Katherinella* Tegland (896). Both *Compsomyax* and *Katherinella* occur in strata of middle Miocene age in Washington. It has been suggested by some authors that *Compsomyax* originated from *Katherinella* by the disappearance of the anterior lateral tooth on the left valve. The hinge bears a resemblance to that of *Clementia* Gray but the posterior cardinal tooth of *Compsomyax* is much more deeply bifid. Furthermore the shells referable to Gray's genus are undulated and possess a deeper pallial sinus. *Marcia* H. and A. Adams, type designated by Kobelt (897), *Venus pinguis* Chemnitz from East Indian seas, belongs to a different group from *Compsomyax*.

Venerella Cossmann (898) has been discussed by Stewart (1930, pp. 223-224), who placed *Compsomyax* as a subgenus of it. We have examined a specimen of the type species of *Venerella* from Hervelon near Hermonville, France, of middle Eocene age, sent to us by Mr. J. L. Staid. Stewart remarked on the small size of European species of this group, and this observation is borne out by the present specimen which is 14.2 mm long and 11.3 mm high, convexity (both valves together), approximately 7.5 mm. A comparison of the hinge of this specimen with that of *Compsomyax subdiaphana* reveals that the posterior cardinal of the right valve is not bifid and the middle cardinal is more broadly trigonal in shape in comparison to those of the corresponding ones on Carpenter's species.

A consideration of these facts leads us to assign *Compsomyax* generic status.

Compsomyax subdiaphana Carpenter
Plate 47, Figures 4, 7; Plate 57, Figure 15

Clementia subdiaphana Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 602, 607, 640, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 88, 93, 126, 1872. — Carpenter, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, p. 56, 1865. [Full description.] "In sinu Pugetiano. . ." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 28, 1878. San Diego well. — Cooper, Calif. State Min. Bur., 7th Ann. Rept. State Mineral, Vol. 7, p. 235, 1888. "Pl. — San Diego well." — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 86, 1889. Dall's record (1878) cited. — Dall, Proc. U. S. Nat. Mus., Vol. 14, No. 849, p. 185, pl. 7, figs. 5, 6, 1891. Various localities, from Port Etches, Alaska, to near entrance of San Francisco Bay, California, in 14-16 fathoms, Recent. — Orcutt, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 60, 1919. Dall's record (1878) cited.

Callista subdiaphana Carpenter, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 144, pl. 13, fig. 4 ("Pliocene, Deadman Island."), 1903. "Pliocene. — San Diego well (Cooper)." Also Pleistocene and Recent.

Marcia subdiaphana Carpenter, Dall, Trans. Wagner Free

Inst. Sci., Vol. 3, Pt. 6, p. 1321, October, 1903. Refers to Cooper's record from "Pliocene of San Diego, California." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 155, pl. 33, fig. 1; pl. 38, fig. 1, 1924. Range, Sannakh Islands, Alaska, to Santa Barbara Islands and San Pedro, California, Recent. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 79, p. 84, 1929. "San Diego Pliocene." Also in Elsmere, Pico, and Holser canyons, Pliocene.

Clementia (Compsomyax) subdiaphana Carpenter, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 334, pl. 17, figs. 10a, 10b, ?15, 1931. "San Diego well (Cooper)." Also earlier records.

Compsomyax subdiaphana Carpenter, K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 93, pl. 10, figs. 1-6, 1958. (Type specimen illustrated.)

Type specimen. — No. 4541, United States National Museum.

Type locality. — "Recent. Puget Sound, Washington (type)." (Palmer, 1958.)

Range. — Late Miocene; Pliocene to Recent. Recent from Sannakh Islands, Alaska, to Cedros Island, Lower California, Mexico, in 2 to 548 meters (1 to 300 fathoms).

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 1404, 28889. L.A.M. 104, 107, 305, 305A. S.D. 75, 294, 295, 302, 2359.

Original description. — "Intermediate between *Clementia* proper and the *prora* group of thin *Callistae*" (1864, p. 602). "Hinge normal, very thin, ashy" (1864, p. 640).

Supplementary description. — ?C. t. ovali, quoad genus valde transversâ, tumidâ, tenuissimâ; pallide ciñereâ, epidermide pallide straminea; subdiaphanâ, sed subcalcareâ, haud porcellanâ; laevi, nisi striis incrementi; haud lunulatâ, umbonibus satis prominentibus: intus, valvâ dextrâ, dentibus anticis cuobus acutis, contiguis, elevalis, postico elongato, acuto, bifido, ligamento parallelo; valvâ sinistrâ dentibus anticis duobus, umbonem versus junctis, acutis, divergentibus, postico elongato, acuto, simplici; sinu palii, ut in Dosiniâ, angusto, angulato, per dimidium interstitii umbones versus porrecto. Long. .72, lat. .58, alt. .34. (Carpenter, 1865.)

Remarks. — The largest and best preserved specimen of this species in the collections at hand is one from Loc. 1404 (CAS), embankment at the corner of India and Upas streets in San Diego. It is 41.4 mm long, 36 mm high, the convexity (both valves together), 24.6 mm.

A number of specimens are in the collections of the Los Angeles County Museum, one of the largest is about 35 mm long. A left valve from Loc. 305 (LAM), although not perfectly preserved, retains much of the hinge which is identical with that of Recent *C. subdiaphana* of comparable size.

There is considerable variation in convexity and in the proportion of length to height in a series of Recent shells of this species. A large specimen in the collections of the California Academy of Sciences from Loc. 5084 (CAS), Port Ludlow, Puget Sound, Washington, is 68.8 mm long, 58 mm high, convexity (both valves together), 40.5 mm. A more elongate specimen from Loc. 19689 (CAS), San Juan Islands, Puget Sound, is 65 mm long, 48.6 mm high, convexity (both valves together), 36.4 mm. The shape and the general characters of the thin-shelled fossils from the San Diego Formation are similar to those of Recent *C. subdiaphana* of comparable size.

Compsomyax subdiaphana is not certainly known to occur in beds earlier than of Pliocene age. Records of this species in beds of Miocene age in some cases are doubtful because some of these occurrences involve the species described as *Cytherea oregonensis* Conrad, a mid-Miocene species which Etherington (889) believed to be referable to the genus *Pitar*. Moore (900), who examined Conrad's type specimen of that species considered it to be a "*nomen dubium.*" The species illustrated by Dall, 1909, under the name of *Marcia oregonensis* Conrad from strata of Pliocene age at Coos Bay, Oregon, is referable to *C. subdiaphana*. The species described by Conrad from Miocene beds at Astoria, Oregon, under the names of *Venus angustifrons* (901) and *Venus brevilineata* (902) (the latter considered by Etherington to be a variety of the former), are Miocene relatives of *C. subdiaphana*. Etherington believed these differed from the Recent species in shape, and "in the absence of the sunken area just anterior to the beak." A fossil cited as "*Marcia augustifrons* (Conrad)", the identification attributed to Durham and Kirk, was cited by Travis (903) as occurring in the Merced beds of Pliocene age in the southwestern portion of the Sebastopol quad. in north central California. Some specimens of *Compsomyax* from strata of Miocene age in Oregon and Washington are very similar to the Recent form. In general, the Recent shells appear to possess a wider ligamental area between the two valves noticeable when viewed from above.

Woodring (904) mentioned that two species, *Lutraria? traskei* and *Dosinia longula*, from the late Tertiary of California described by Conrad in 1856, may be closely comparable to *C. subdiaphana* but that the types of the two fossils "are so inadequate that the names may be considered nomina dubia." Grant and Gale (1931, pl. 22, fig. 1) published an illustration of the holotype of *Dosinia longula* which, unless deformed, does not closely resemble typical *C. subdiaphana*.

The species described as *Saxidomus gibbosus* by Gabb (905) from the Pliocene of Humboldt Co., Calif., was based on a large, globose form of Carpenter's species. Most authors do not consider it to be of taxonomic significance.

The form described as *Callista subdiaphana* var. *pedroana* by Arnold (1903, p. 144, pl. 13, fig. 2) from the Lower San Pedro beds at San Pedro, California, of Pleistocene age, is generally considered to be only a small valve of *Compsomyax subdiaphana*.

Clementia obliqua Jukes-Browne (906), described from "Porto Rico" (mistaken locality), is identical with Carpenter's species.

Species very similar to *Compsomyax subdiaphana* occur in the Miocene of Japan. The species described as *Meretrix iizukai* Yokoyama (907), as pointed out by Stewart, is remarkably similar in shell characters observable in the illustrations. More recently "*Clementia (Compsomyax) subdiaphana yazawaensis* Otuka" (908) and "*Clementia (Compsomyax) aff. subdiaphana* Carpenter" (909) have been cited by Otuka from the Miocene of Japan.

GENUS *SAXIDOMUS* CONRAD

Saxidomus Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 249, 1837. Sole species, *Saxidomus nuttalli* Conrad. — Dall, Proc. U. S. Nat. Mus., Vol. 26, No. 1312, p. 356, 1902. "Type, *S. nuttallii* Conrad." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1280, 1903. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 341, 1931.

Type species (by monotypy). — *Saxidomus nuttalli* Conrad.

Range. — Early Miocene to Recent. Recent from San Quintín, Lower California, Mexico, to Japan. ?Chile. Recent from the intertidal zone to 37 meters (20 fathoms).

Description. — Shell large, rude, chalky, ovate-quadrate, with low beaks, and concentric usually feeble sculpture; the ligament is strong and not depressed; there is no defined lunular area or escutcheon; internal margins smooth; pallial line with a deep, rounded sinus; hinge with three cardinals in each valve; the posterior right cardinal bifid; anterior laterals closely adjacent to the cardinals, one of the left ones often in line with the anterior cardinal. (Dall, 1902).

Remarks. — The exact relationship of *Saxidomus* to similar genera in the Veneridae is not certainly known. Romer (910) long ago discussed this genus and the species assigned to it. Grant and Gale ventured the opinion that the cardinal teeth may have been multiplied by division in a manner comparable to some of the paphias.

The earliest known species appear in the early Miocene of California. Species assigned to *Saxidomus* in beds of pre-Miocene age, such as "*Saxidomus* (?) *noblei*" Dickerson (911), from the early Eocene of California, are almost certainly referable to other genera. The type of that Eocene species is poorly preserved and the hinge is unknown.

We have examined a cast of the holotype of *Saxidomus popofianus* Dall (912) from beds of presumably medial Tertiary age on the Shumagin Islands. The species is based upon an internal cast about 51 mm long. The pallial sinus is short, V-shaped, rounded at the end, extending forward only about 19 mm from the posterior end. We can add nothing concerning the affinities of this form.

Saxidomus is represented in the late Tertiary of California by four or five species and in the Pleistocene by two. Two species and one subspecies now live in west American waters in the region between Alaska and northern Lower California. Two and perhaps three species have been reported from strata of Miocene age in Japan. One species now lives in Japanese waters.

This genus is generally considered to be limited in distribution, both fossil and Recent, to the north and northeast Pacific. The species described from Chile as *Venus opacus* Sowerby (913) has been referred to various genera by different authors. Römer, and later Carcelles and Williamson (914), assigned it to *Saxidomus*. More recently it was placed in *Eurhomalea* Cossmann (915) by Soot-Ryen (916).

Von Ihering (917) believed that *Saxidomus* originated along the west coast of North America and that it reached the southern portion of the west coast of South America during the Pleistocene. We have not studied specimens from Chile.

Key to Species And Subspecies of *Saxidomus*

A. Anterior end broad and long . . . . . (subspecies) *latus*

B. Anterior end rather narrow and short . . . . . *nuttalli*

Saxidomus nuttalli Conrad

S[axidomus]. nutalli Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 249, pl. 19, fig. 12, 1837. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 174, 182, 1912. "San Diego — Purisima." — Weymouth, Calif. State Fish Game Comm., Fish Bull. No. 4, p. 35, pl. 7, figs. 1 and 2, 1920. "Bolinas Bay to San Diego," California. — Grant and Gale, Mem. San Deigo Soc. Nat. Hist., Vol. 1, p. 341, pl. 18, fig. 11, 1931. Late Miocene to Recent, California. — Fitch, State Calif. Dept. Fish Game, Fish Bull. No. 90, p. 64, fig. 30, 1935. "Humboldt Bay, California, to San Quintín Bay, Baja California," Recent. — Abbott, American Sea Shells (D. Van Nostrand Co., Inc.; New York), p. 417, pl. 31, fig. 1, 1954. "Humboldt Bay, California, to Lower California.

Type specimen. — Two syntypes No. 43.12.6.76 and 55.3.14.48, British Museum (Natural History) (A. M. Keen, Veliger, Vol. 8, No. 3, p. 169, 1966).

Type locality. — "Inhabits the coast of California and Sta. Diego, burrowing into soft clay-stone accompanying the Pholades, Cummingae, & c."

Range. — Middle Miocene (Temblor (918); Topanga) to Recent. Recent, Humboldt Bay, California, to San Quintín Bay, Lower California, Mexico. In bays and lagoons at depths of 12-18 inches in sandy mud or sand which is usually exposed at low tide. To a depth of 37 meters (20 fathoms).

Occurrence in San Diego Fm. — "San Diego-Purisima" (J. P. Smith). L.A.M. 305A, 318, 319, P.87: 58442. U.C.L.A. 312, 1386.

Original description. Shell suboval; disk rough, with concentric striae, elevated on the posterior slope; posterior extremity truncated; colour white, with brown spots and stripes about the umbo and ligament margin. Length, two inches. (Conrad.)

Remarks — Several specimens of this species are present in the collections of the Los Angeles County Museum from near the Mexican boundary. Three of these from Loc. 319 (LAM) retain both valves, the largest is 119 mm long, 89 mm high and the convexity (both valves, somewhat compressed together), 59 mm. Some of the valves are 4 mm thick. The anterior portion of a valve from Loc. 318 (LAM), is 101 mm long, 89 mm high, the convexity, approximately 29 mm. Three specimens of this species, also from near the Mexican boundary, are in the collections of the University of California at Los Angeles. The shell characters of all these specimens are similar to those of Recent *Saxidomus nuttalli.*

An imperfect cast from Sand Rock Canyon, San Diego, 64.2 mm long, in the collections of San Diego Society of Natural History is probably referable to *S. nuttalli.*

The generally more northern species *Saxidomus*

giganteus Deshayes (919) has a generally smaller, more rounded, much smoother shell.

Saxidomus vaquerosensis Arnold (920), described from beds of middle Miocene age, has a narrower outline and more regular and finer concentric sculpture, and, according to its author, is probably the precursor of *S. nuttalli*. "*Saxidomus* cf. *vaquerosensis* Arnold" was recorded by Hertlein and Jordan (921) from beds of middle Miocene age in Lower California.

Khomenko (922) cited a species under the name of *S. vaquerosensis* from the Matchgar series, which he considered to be of early Miocene age on the Schmidt Peninsula, Kamtschatka. Confirmation of this identification or of close relationship with the west American species is desirable.

A species from beds of Miocene age in Japan, cited by Nomura and Hatai under the name of "*Saxidomus Nuttallii* Conrad" was later named *Saxidomus nomurai* by Hatai and Nisiyama (923).

Saxidomus nuttalli reaches a length of about 171 mm (7 inches). Smith (924) discussed the ecology and growth of this species.

Gavala y Laborde (925) believed that resemblance existed between *Cochlea gilva* Martyn (926) from Poulo Condore Islands in the South China Sea, South Vietnam, and *Saxidomus nuttalli* Conrad illustrated by Sowerby (Thes. Conch., Vol. 2, pl. 164, fig. 10). However, an inspection of Martyn's illustration supports Solem's assignment of the East Indian species to a different genus and family (see *Trapezium sowerbyi* Hidalgo, Solem, Proc. Malacol. Soc. London, Vol. 31, Pt. 2, p. 70, pl. 5, figs. 1, 2, 1954).

Saxidomus nuttalli latus Stewart
Plate 50, Figures 8, 10

Saxidomus nuttalli latus Stewart, in Woodring, Stewart, and Richards, U. S. G. S., Prof. Paper 195, p. 94, pl. 8, fig. 15; pl. 16, fig. 8 (as *Saxidomus nuttallii latus*); pl. 33, fig. 6, 1940, issued June 7, 1941.

Saxidomus sp. aff. *S. nuttalli* Conrad, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 52, pl. 24, figs. a, b, 1968. "Pliocene in Balboa Park, San Diego."

Type specimen. — No. 495782, United States National Museum.

Type locality. — Loc. 87 (U. S. G. S.), "North Dome, sec. 9, T. 22 S., R. 18 E.; 1,520 feet north, 625 feet east; divide between Arroyo Pequeño and Arroyo Finito," Kettleman Hills, San Joaquin Co., California. San Joaquin Formation, late Pliocene.

Range. — Etchegoin, San Joaquin, and San Diego formations, middle Pliocene, California.

Occurrence in San Diego Fm. — C.A.S. 12051. S.D. 70.

Original description. — ". . . .has a wider and longer anterior end than the living California *S. nuttalli.*"

Remarks. — Two valves of this subspecies are present in the Henry Hemphill collection from the San Diego well. The larger valve, a right valve, 119 mm in length, is imperfect; lacks the ventral portion of the valve but the anterior dorsal margin is more flaring, broader, and the posterior dorsal margin is straighter than that of Recent *Saxidomus nuttalli* Conrad. Probably some variation exists in a series of specimens. Stewart mentioned that "some specimens from the upper *Mya* zone have smaller adductor scars and a shallower pallial sinus than the Recent form, but the figured specimen from that horizon has a deep pallial sinus."

Another feature noticed on the larger valve at hand is the prominent and longer nymph plate and this no doubt is because of the straighter dorsal margin on the subspecies. This specimen agrees well with Stewart's illustrations (especially his plate 16, figure 3).

The enumerated differences characterizing the subspecies are more noticeable on larger than on smaller specimens. A left valve from the San Diego well, length 72 mm, height, approximately 51 mm, apparently has a straighter posterior dorsal margin than that on Recent specimens of comparable size.

GENUS *CHIONE* MEGERLE VON MÜHLFELD

Chione Megerle von Mühlfeld, Gesellschaft Naturf. Freunde zu Berlin, Jahrg. 5, p. 51, 1811. Species cited: "*Chione Dysera*" with references to "Linn. Syst. Nat. Gen 309. Sp. 4.a" and "Chemn. Conch. 6. t. 28. f. 287-290"; "*Chione Gallina*" with references to "Linn. Syst. Nat., Gen 309, Sp. 9, beta 114.a" and "Chemn. Conch. 6. t. 30, f. 308-310." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 318 1931. Type as indicated by Gray.

Type species (designated by Gray, Proc. Zool. Soc. London for 1847, p. 183).—"*Chione Dysera*" [Linneasu]. [The figure cited by Linnaeus (Syst. Nat., p. 685, 1758) to represent typical *Venus dysera* was based on Argenville, Conch., pl. 24, fig. K, which may represent *Venus plicata* Gmelin (Linn. Syst. Nat., ed. 13, Tom. 1, Pars 6, p. 3276, 1791. "in mari indico". References to "Argenv. Conch. t. 21. f. k", "Valent. Abh. t. 15, f. 21.", "Chemn. Conch. 6. t. 28. f. 295-297."). The figures cited by Megerle von Mühlfeld as representing *Venus dysera* are those of Chemnitz (Syst. Conchyl.-Cab., Bd. 6, pl. 28, figs. 287-290, 1792) with the localities (p. 296) "westindischen Strande" and "Jamaica". These figures represent *Venus cancellata* Linnaeus (Syst. Nat., ed. 12, p. 1130, 1767. "Habitat in Oceano Africano." Reference to Gualtieri, Test., pl. 88, fig. D.), the species traditionally accepted as type of *Chione*. We follow this practice at least until a definite settlement of the selection of the type species is sanctioned by the Internatl. Comm. of Zool. Nomencl. Dodge (Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 89-92, 1952) has given a full discussion of the problem of the type species of *Chione*. *Venus cancellata* Linnaeus is well illustrated by K. V. W. Palmer (Palaeontogr. Americana, Vol. 1, No. 5, p. 359 (151), pl. 68 (37), figs. 1-6, 6a, 7, 8, 11, 15, 1927), with the range from Cape Hatteras, North Carolina, to Brazil, the Gulf of Mexico, and West Indies).]

Range. — Late Oligocene or early Miocene to Recent. Recent in warm temperate and tropical waters, from the intertidal zone to 232 meters (127 fathoms).

Description. — Subtrigonal, thick, anteriorly rounded, posterior ventral margin somewhat pointed, beaks prosogyrous; lunule and escutcheon well defined; concentric lamellae well developed, and may or may not be crossed by radial sculpture; radial ribs usually present; ligament sunk below escutcheon; hinge of left valve with

2 or 3 cardinals, the posterior one usually bifid, right valve with 3 in addition to a posterior ridge, the anterior one small, the middle and the posterior ones large, usually slightly grooved; pallial sinus short; inner margins of the valves finely crenulated.

Remarks. — About 30 species and 7 subspecies of *Chione* have been described from the Cenozoic of western North America. Many of these species have been discussed and illustrated by Parker (927). Some of the tropical species were separated later into different genera by Olsson (1961). Three species are known to occur in the San Diego Formation.

The earliest occurrence of *Chione s. s.* in southern California is in strata of middle Pliocene age. Species of this subgenus now live in tropical, subtropical and warm temperate American waters. Two species of this subgenus range north to Point Mugu, California (34° N.) but during Pleistocene time one of these ranged north to Tomales Bay (38° 10'N.). *Chione fluctifraga* Sowerby, the type of *Chionista* Keen, ranges north to Morro Bay, San Luis Obispo Co., at the present time.

Anomalocardia Schumacher has a hinge similar to that of *Chione* but the concentric sculpture is composed of prominent, thick, concentric rugae rather than lamellae. The concentric sculpture is predominant.

Iliochione Olsson (928) was recently proposed to include tropical west American species formerly placed in the genus *Anomalocardia.*

Key To Subgenera Of *Chione*

A. Ligament anteriorly extending deeply into the valve and above the nymph; pallial sinus short but well developed and angular at the end . . . . . *Securella*

B. Ligament extending only slightly into the valve and onto the nymph; pallial sinus very short or almost lacking, somewhat rounded at the end . . . . . *Chione s. s.*

SUBGENUS *CHIONE* S. S.

Key to Species of *Chione* s. s.

A. Concentric lamellae evenly spaced; radial ribs coarse . . . . . *undatella*

B. Concentric lamellae very closely crowded; radial ribs fine . . . . . *allisoni*

Chione (Chione) allisoni n. sp.
Plate 51, Figures 11-16

Description. — Shell of holotype (a left valve) of medium size, elongately trigonal, moderately thin, moderately convex; sculpture consisting of rather fine radial ribs which may be bifid or trifid, these are crossed by thin, low, concentric lamellae, moderately spaced on the early portion of the valve, but over most of the shell these are very closely spaced; lunule with fine sculpture similar to the remainder of the valve; escutcheon on left valve, smooth, steeply sloping; hinge with a thin anterior cardinal which slopes forward, a fairly thick central tooth and a narrow posterior ridge which extends from beneath the beak almost to the dorsal margin of the hinge plate; pallial sinus very short, pointed; interior margin finely denticulated. Right valve (paratype) similar to the left except that the escutcheon is less well developed and on some valves less well defined; hinge with a short anterior tooth fused to the lunular margin, central and posterior teeth well developed. Dimensions of the holotype, length 32.6 mm, height 27.2 mm, convexity (one valve) 10.2 mm.

Holotype, a left valve, and paratypes, in the collection of the San Diego Society of Natural History. Paratypes, in the collection of the San Diego Society of Natural History. Paratypes also deposited in the Department of Geology, California Academy of Sciences, and in the Los Angeles County Museum.

Type locality. — Loc. 222 (San Diego State College), two miles south-southeast of Mt. Soledad and 200 yards north of Kate Sessions Elementary School; shell bed exposed at middle of south facing bank (about six feet above house level) at rear of lot on northeast corner of Edgeworth Road and Blackmore Court, community of Pacific Beach, city of San Diego, collected by Charles N. Howell, 1964.

Range. — Known only from the type locality and vicinity.

Occurrence in San Diego Fm. — S.D.S.C. 222, 223.

Remarks. — About 75 valves of this species have been available for study. The largest specimen, a right valve from Loc. 222 (SDSC) is 35.4 mm long and 31.8 mm high. A more rounded specimen from Loc. 223 (SDSC), is 31.4 mm long and 31.2 mm high. In general the shells are longer than high.

The shape and general appearance of the valves are somewhat similar to that of *Chione undatella* Sowerby. However, all specimens of this new species differ form *C. undatella* in the thinner shell, finer radial ribs, and fine, low, extremely closely spaced concentric lamellae. One specimen in the lot has rather coarse radial ribbing and in shape somewhat resembles that of *C. californiensis gealeyi* Parker (929).

The generally fine radial ribbing and low, closely spaced, concentric lamellae, lend a general resemblance to *Chione (Nioche) asperrima* Sowerby (930), the type species of *Nioche* Hertlein and Strong. However, the general shape, lack of radial ribs along the posterior dorsal margin, the kind of sculpture on the early portion of the valves, as well as the short pallial sinus, all more closely resemble those features on *C. undatella* than on any other species. For this reason we assign the new species here described to *Chione s. s.* rather than to *Nioche* Hertlein and Strong.

This species is named for the late Dr. Edwin C. Allison, Department of Geology, San Diego State College in recognition of his contributions to the knowledge of the stratigraphy and paleontology of Lower California.

Chione (Chione) cf. *C. (C.) undatella* Sowerby

The following references, type specimen, type locality and description refer to typical *C. undatella.*

Venus undatella Sowerby, Proc. Zool. Soc. London, p. 22, April 6, 1835. — Sowerby, Thes. Conch. Vol. 2, p. 711, pl. 153, fig. 22, 1853. "Found on the shore at the island of Tres Marias, Gulf of California."

Venus neglecta Sowerby, Beechey's Voy., p. 151, pl. 41, fig. 8, 1839. "Inhabits sandy mud on the coast of Central America."

Venus simillima Sowerby, Thes. Conch., Vol. 2, p. 708, pl. 153, figs. 17, 18, 1853. "California." — Reeve, Conch. Icon., Vol. 14, *Venus*, species 44, pl. 13, fig. 44, 1863. "Hab. San Diego, California."

Chione undatella Sowerby, Hertlein and Strong, Zoologica, Vol. 33, pt. 4, p. 182, 1948. "Mugu Point, California, to Paita, Peru."

Chione (Chione) undatella Sowerby, Parker, Jour. Paleo., Vol. 23, No. 6, p. 581, pl. 89, fig. 1; pl. 90, figs. 12, 13, 1949. Recent, Cedros Island, Lower California, to Panama. Pleistocene, San Pedro, California. Late Pliocene and early Pleistocene of the Gulf of California and the Galápagos Islands.

Type specimen. — British Museum (Natural History).

Type locality. — "Hab. in Sinu Californiensi. (Island of Tres Marias.)" "Found on the shore."

Range. — Middle Pliocene to Recent. Recent, Mugu Point, California, to Panama and the Galapagos Islands; from the beach to 91 meters (50 fathoms), usually on sand or sandy mud bottom.

Occurrence in San Diego Fm. — L.A.M. 302, 305.

Original description. — Ven. testâ rotundato-ellipticâ, crassâ, albidâ, fusco maculatâ punctatâ et undatim pictâ, costellis radiantibus confertis, aliisque decussantibus undulatis sublamellosis; latere antico breviore, postico subdeclivi, marginibus depressis; margine ventrali rotundato, intùs crenulato: Long. 1.6; lat. 1., alt. 1.5 poll. (Sowerby.)

Remarks: The specimens here provisionally referred to *Chione undatella* are fragments the largest of which, the umbonal portion of a right valve 22mm high, retain the hinge. These were embedded in matrix along with *Megapitaria squalida*, *Anadara trilineata*, and *Pecten healeyi*. The shell characters, especially the sharp, evenly and rather closely spaced concentric lamellae, are identical with Recent specimens of *C. undatella* from San Ignacio Lagoon, Lower California, and elsewhere.

The shell of this species is similar to that of *C. californiensis* Broderip (931) but the valves are generally slightly more inflated and ornamented with sharper, more numerous, more closely spaced concentric lamellae, about 4 to 6 per centimeter on the middle of a valve.

Study of a large series of specimens of the present species reveals so much variation that we are inclined to refer numerous named variants to *C. undatella* including *Venus neglecta* Sowerby, 1835; *Venus nuttalli* Conrad, 1837; *Venus entobapta* Jonas, 1845; *Cytherea sugillata* Jonas, 1845; *Venus perdix* Valenciennes, 1846; *V. simillima* Sowerby, 1853; *V. excavata* Carpenter, 1857; *V. bilineata* Reeve, 1863; *Chione undatella* var. *taberi* Parker 1949.

SUBGENUS *SECURELLA PARKER*

Securella Parker, Jour. Paleo., Vol. 23, No. 6, p. 587, November, 1949.

Type species (by original designation). — "Genotype. — *Venus securis* Shumard (Pl. 94, figs. 8, 12, 19; pl. 95; pl. 95, fig. 6)." [*Venus securis* Shumard, Trans. Acad. Sci. St. Louis, Vol. 1, No. 2, p. 122, 1858. "Collected by Dr. Evans in gray, fine-grained sandstone of the Miocene age, at the mouth of Coos Bay, Cape Blanco, and on the shores of the Columbia short distance above Astoria, Oregon Territory. At all of these localities it is quite common." — Dall, U. S. G. S., Prof. Paper No. 59, p. 120, pl. 11, fig. 8; pl. 13, figs. 2, 8, 9, 1909 (as *Chione securis*). Coos Bay, Oregon, late Miocene [Pliocene]. (A reprint of Shumard's original description on pp. 187-188). — Trumbull, Jour. Paleo., Vol. 32, No. 5, p. 903, pl. 117, figs. 1-3, September, 1958 (as *Chione (Securella) securis*. Lectotype and hypotype illustrated).

Range. — Late Oligocene to middle Pliocene, northeastern Pacific, Alaska to California; Kamtschatka, and Japan.

Original description. — Ligament deeply sunken in shell, wedging out between hinge plates; right, middle and posterior cardinals slightly grooved; left middle cardinal deeply grooved so that posterior portion of tooth larger and higher than anterior; sculpture of evenly spaced thin concentric ridges arising from a layer of concentrically disposed shelly material; this layer underlain by distinct radial ribs not visible on the surface; this condition of exclusively concentric ribs usually modified by erosion of shell, so that the common worn and leached specimens exhibit ornamentation with varying degrees of prominence and numbers of radial and concentric ribs; lunule deeply impressed, it is never removed, but escutcheon is often obliterated at an early state by erosion. For hinge characters, see also *S. ensifera* (Dall) (pl. 89, fig. 4). (Parker.)

Remarks. — The smooth surface on uneroded shells, crossed only by concentric lamellae, is a shell character which serves to separate this subgenus from *Chione s.s.* and *Chionopsis* Olsson. The thin, erect, concentric lamellae of *Securella* are quite different from the thicker, curved lamellae of *Lirophora* Conrad. The deep ligamental grooves which wedge out under the posterior dorsal margins of the valves are quite different from the corresponding grooves of the other subgenera of *Chione* mentioned above. Thirteen species from the medial Tertiary of the western United States were referred to *Securella* by Parker.

Chione (Securella) kanakoffi n. sp.

Plate 49, Figures 1, 3, 4, 5, 6;
Plate 51, Figures 4, 5, 6, 7, 10

Description. — Shell large, thick, ovately trigonal in outline, evenly convex; beaks prosogyrous; anterior end rounded and merging into the broadly rounded ventral margin, posterior dorsal margin very gently rounded to the posterior end which is very broadly rounded into the ventral margin with only a faint trace of a posterior truncation; lunule broadly cordate, concave, bounded by an impressed line; escutcheon extends to the posterior end and is crossed by concentric lamellae; a narrow, very faintly depressed area extends parallel to and just anterior to the posterior dorsal margin; sculpture consists of thin concentric lamellae spaced about 5 or 6 mm apart over much of the valve but more closely spaced toward both ends and along the ventral margin, the areas between the lamellae are smooth but radial riblets are exposed where

the surface is eroded, these are fine on the umbo but coarser toward the ventral margin. Dimensions: length 129 mm; height 122 mm; convexity (both valves together) 76 mm.

Hinge of right valve (paratype) with three cardinals, the anterior one rather thin, the middle and posterior ones fairly thick and medially grooved; a nymph plate about equal in length to the posterior cardinal occurs above it; a ligamental groove extends deeply under the dorsal margin; the base of the hinge is decidedly convex (upward) from below the middle cardinal to the posterior margin; pallial sinus short, V-shaped and extends forward 44 mm from the posterior margin, and points toward about the lower portion of the anterior adductor muscle impression; adductor impressions large and deep; margin of valve nearly smooth, with faint indications of radial sculpture which is covered by a calcareous layer. Hinge of left valve (paratype) similar to that of the right valve, but with a thinner, faintly grooved posterior cardinal, a fairly thick and medially grooved central one and a fairly thick anterior cardinal.

On some specimens the ventral margin, where eroded, is denticulated where the underlying radial sculpture is exposed.

Type specimens. — Holotype, right valve, and paratypes, Invertebrate Paleontology Collection, Los Angeles County Museum.

Type locality. — Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U. S. G. S. topog. map, San Ysidro quad., rev. 1953); G. P. Kanakoff, collector. Paratype from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U. S. G. S. topog. map, San Ysidro quad., ed. 1943); G. P. Kanakoff, collector. Paratype from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM), at the same elevation; fossils in float slump and consolidated boulders and silt and sandstone, and silt in place; G. P. Kanakoff, collector.

Additional occurrences in the San Diego Fm. — C. A. S. 1181, 28885, 28892. L. A. M. 305A, 318, 319. S. D. 4. U. C. L. A. 294, 312, 2359. S. D. S. C. 32.

Range. — Known only from the type locality and vicinity of San Diego.

Remarks. — This species is well represented in the collections of the Los Angeles County Museum from near the Mexican boundary by two specimens with both valves together and by ten large single valves in various states of preservation and by many fragments, and by more than 100 small ones. The shell of one of the fragments is 9 mm thick. The amount of radial sculpture exposed on the exterior of the valves is in direct proportion to the amount of erosion of the surface. Three fragments of valves, the largest 90.5 mm long are present in the collections of the University of California at Los Angeles from the same area as well as one right valve in the collections of San Diego State College. Small specimens in the collections of the California Academy of Sciences probably also came from near the Mexican boundary and from other localities.

Chione kanakoffi n. sp. more closely resembles *Chione semiplicata* Nomland (932), which was described from beds of late Miocene age, than any described species. It differs from that species in the more expanded and rounded anterior end, the more evenly convex valves and less flattened area along the posterior dorsal margin and in the more widely spaced concentric lamellae.

Compared with *Chione margaritana* Anderson and Martin (933), the shell of the new species is more orbicular in outline, the height is greater in proportion to the length and the umbos are broader.

Compared to *Chione panzana* Anderson and Martin (934) the valves of the new species are more highly convex, the posterior end is more rounded, the lunule is broader and the concentric lamellae are much more widely spaced.

Parker (935) placed *C. margaritana* in the synonymy of *C. panzana* but a comparison of the type specimens of these two species reveals that they apparently represent distinct species. Two other elongate species, *C. vickeryi* Wiedey (936) and *C. schencki* Loel and Corey (937), described from beds of Miocene age, were considered by Parker (1949, p. 584) to be founded upon deformed specimens which he placed in the synonymy of *C. semiplicata* Nomland. The two specimens are no doubt somewhat deformed but whether they are identical with *C. semiplicata* may be open to question.

A comparison of *C. kanakoffi*, new species, with *C. elsmerensis* English (938) reveals that the shell of the new pecies is more rounded posteriorly, and the radial ribbing (exposed by erosion) is much finer.

Small specimens of this new species were cited by the senior author (939) from the San Diego Formation under the name of *Chione fernandoensis* English. More than one hundred valves from Loc. 305A (LAM), 4 to 23 mm in length, of juvenile *Chione kanakoffi* n. sp. have been available for study. These have been compared with a cast of the specimen of *Chione fernandoensis* (940) illustrated by English, later cited as the holotype by Parker, and also with a cast of the specimen illustrated and cited as a paratype by Parker. Keen and Bentson (941) evidently considered these two specimens to be syntypes. We have also had available for comparison specimens of *C. fernandoensis* from Loc. 710 (CAS), Elsmere Canyon, Los Angeles Co., California.

None of the small specimens from the San Diego Formation are definitely referable to *C. fernandoensis* and we consider them to be juvenile forms of *C. kanakoffi* n. sp.

The general appearance of *C. kanakoffi* n. sp. is that of a plumper form, more rounded, more convex, the beaks more projecting and the posterior dorsal margin is not so straight and not so strongly angulated and the lunule is more depressed. The concentric lamellae on these juvenile forms are often greatly eroded but there are about 10 to 18 on specimens 10.8 to 18 mm long. Some of these valves were bored by gastropods.

Over fifty valves of a small species of *Chione*, 4 to 20 mm in length, from Loc. 291 (LAM), Pico Formation, Humphrey's quad., are identical with valves of the same size from the San Diego Formation.

Parker (942) illustrated four specimens under the name of *Chione (Anomalocardia) fernandoensis*. His figures 14 and 16 of a specimen from Elsmere Canyon apparently represent *C. fernandoensis*. His figures 13 and 18, indicated as a paratype, represent a specimen with rather highly projecting umbos. This apparently represents a different species resembling in general outline species

such as *C. securis* Shumard. Parker's figures 7, 8, and 15 represent specimens of Pleistocene age and do not closely resemble typical *C. fernandoensis.*

Chione mariae d'Orbigny (943) now living in tropical west American waters, is more trigonal in outline and has fewer concentric lamellae than either juvenile *C. kanakoffi* n. sp., or *C. fernandoensis.*

GENUS *PROTOTHACA* DALL

Protothaca Dall, Proc. U. S. Nat. Mus., Vol. 26, No. 1312, p. 364, December 29, 1902. — Frizzell, Proc. Geol. Soc. Amer. for 1934, pp. 387-388, 1935. Type as indicated by Dall. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 304, 1961. Original designation of type species cited.

Type species (by original designation). — "Type *Venus thaca* Molina (= *V. dombeyi* Lamarck)." [*Chama thaca* Molina, Saggio sulla Storia Naturale del Chile, p. 178. 1782. See also English translation, Vol. 1, pp. 141, 243, 1808 (Middletown, Connecticut); a different edition, 1809, pp. 167, 287. — Olsson, 1961, p. 304, pl. 41, fig. 1; pl. 53, figs. 1, 1a (as *Protothaca (Prothothaca) thaca*). Lima, Peru, to Chile. *Venus dombeii* Lamarck, illustrated by Reeve, Conch. Icon., Vol. 14, *Venus*, pl. 9, fig. 29, April, 1863. "Hab. Valparaiso Bay; Cuming." See also Riveros Zuñiga and Gonzales Reyes, Rev. Biol. Mar., Vol. 2, Nos. 2 and 3, p. 142, fig. 32 (p. 143 as *Venus dombeyii)*, fig. 33 (as *Venus thaca*), fig. 34 (as *Venus ignobilis*). Ancon, Peru, to Puerto Montt, Chile.]

Range. — Eocene to Recent (Frizzell). Entirely or almost entirely around the Pacific basin. Western North America from middle Miocene (944) to Recent. Recent from the intertidal zone to about 46 meters (25 fathoms).

Original description. — Shell ovate, convex, coloration white or dull; surface dull, reticulately sculptured, the radials usually stronger; sculpture more or less distinctly divided into three areas, the middle of the valves with chiefly radial, the anterior radial and scabrous, the posterior with irregularly concentric sculpture; lunule and escutcheon of the left valve, sharply circumscribed; in the type species the right valve shows no escutcheon and the margin partially overlaps that of the left valve but does not conceal the ligament; middle cardinals grooved or bifid; pallial sinus free, moderate, pointed in front; the inner margins sharply crenulated in the typical section. (Dall.)

Remarks. — Some of the west American species assigned to *Protothaca* do not have coarsely crenulated inner margins nor does the right valve overlap the left. However, many others do have crenulated margins and the right valve slightly overlaps the left one posteriorly. This latter feature, although slight, is noticeable on some specimens of *Protothaca staminea, P. laciniata* and *P. grata.* For these reasons we leave *P. staminea* in the typical subgenus of *Protothaca.*

Protothaca is confined in its distribution almost entirely to the borders of the Pacific basin. Frizzell in 1935 stated that about 25 species of this genus were known and several have been described since. Von Ihering (945) stated that the genus occurred in the Eocene faunas of Patagonia and that it reached California in the middle Miocene. Later, Marwick (946) outlined the route of migration to Japan in Pliocene time and to New Zealand in the Pleistocene and this was accepted by Frizzell, 1935. In the latest check list of the Tertiary mollusks of Japan by Hatai and Nisiyama (947), three species assigned to *Protothaca* are cited as occurring in strata of Miocene age in that country.

Novathaca Habe (948) was proposed for *Chione euglypta* Sowerby from Japan, a species somewhat similar to *Protothaca staminea* Conrad.

A subgenus of *Protothaca*, *Tropithaca* Olsson (949), was recently proposed with *Protothaca grata* Say, a west American species, as type. The escutcheon is much reduced in size and the pallial sinus is shorter than that of *Protothaca s. s.*

Tuangia Marwick (950), type *Venus crassicosta* Deshayes, which occurs in New Zealand, also is very similar to *Protothaca*, but it has coarser sculpture than the west American forms.

The crenulated inner margin, more distinct lunule and narrower pallial sinus are features which serve to separate *Protothaca* from *Venerupis* Lamarck.

Key to Subgenera of *Protothaca*

A. Sculpture coarse, the radial usually the stronger; lunule well defined; right valve sometimes overlapping the left posteriorly; valves decidedly inflated . . . *Protothaca s. s.*

B. Sculpture fine, the concentric strongly elevated; lunule but feebly defined; right valve not overlapping the left posteriorly; valves flattened . . . . . *Callithaca*

SUBGENUS *PROTOTHACA* S. S.

Protothaca (Protothaca) staminea Conrad

V[enus]. staminea Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, pt. 2, p. 250, pl. 19, fig. 15, 1837. Not *Cytherea staminea* Conrad, 1839. [Referred to the genus *Antigona* by recent authors. See Bull. Amer. Paleo., Vol. 25, No. 94B, p. 61, 1941.]

Tapes staminea Conrad, [?] Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11, 1878. Later Tertiary of San Diego. — [?] Orcutt, West Amer. Sci., Vol. 6, Whole No. 45, p. 70, 1889. Pacific Beach, Tertiary. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 150, 1903. "Found in the Pliocene at Pacific Beach and Russ School." — Arnold, U. S. G. S., Prof. Paper No. 47, p. 28, 1906. "Pacific Beach," "San Diego Formation."

Paphia staminea Conrad, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 173, 182, 1912. [Species attributed to Carpenter.] "San Diego-Purisima," lower Pliocene. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 157, 1924. "Pliocene" of "San Diego." — Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, opp. p. 78, 1929. "San Diego Pliocene."

Venerupis (Protothaca) staminea Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 330, 1931.

Arnold's record from San Diego Pliocene cited.

Protothaca staminea Conrad, Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 66, fig. 32, 1953. "Range: Aleutian Islands to Cape San Lucas, Baja California."

Type specimen. — Two syntype lots Nos. 55.3.14.40 and 65.5.20.123, British Museum (Natural History) (A.M. Keen, Veliger, Vol. 8, No. 3, p. 169, 1966).

Type locality. — "Inhabits the coast of California, with the above." [That is, *Venus nuttalli*, "Inhabits the coast of California, Sta. Barbara, and Sta. Diego."]

Range. — (cf.) middle Miocene; late Miocene to Recent from the Aleutian Islands to Cape San Lucas, Lower California, Mexico, from shore to 46 meters (25 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305.

Original description. — Shell suboval, or suborbicular, convex, with numerous crowded radiating striae, and finer concentric lines, most distinct on the anterior side; posterior extremity direct; ligament margin nearly parallel with the base; colour variegated with yellowish and brown, and with brown angular spots; cardinal teeth compressed; sinus of pallial impression profound. Length, one and a half inches. (Conrad.)

Remarks. — Fragments of the anterior end of a valve are present in the collections of the Los Angeles County Museum from near the Mexican boundary. The largest fragment, 29 mm long, retains the radial ribbing and lunular area. The shell characters agree well with the corresponding sculpture on valves of *Protothaca staminea* of the same size.

Two casts of a bivalve resembling this species, collected by Charles Sternberg in the San Diego Formation, are in the collections of the Academy. There is no information as to the exact locality from which they came, but the matrix, gray sandstone, is similar to that of other species which were collected near and under the Mercy Hospital foundation on Sixth Street in San Diego. The outline, traces of radial ribbing and all observable characters are similar to those of *Protothaca staminea*. The largest specimen is 65 mm long and 62 mm high.

One valve labelled as coming from Loc. 122 (LAM) Pacific Beach, may have come from beds of Pleistocene age.

This species has been recorded by several authors as occurring in the Pliocene beds at San Diego. It also is well known in beds of Pliocene, and Pleistocene age, along the west coast of North America. It apparently ranges from middle Miocene age but Loel and Corey did not cite it in their list of Temblor species.

Protothaca staminea is represented by a number of forms occurring in waters of the northeastern Pacific, including those described as *Venerupis petitii* Deshayes, 1839, *Tapes ruderata* Deshayes, 1853, *Tapes staminea* var. *orbella* Carpenter, 1864, and *Protothaca staminea* var. *spatiosa* Dall, 1916. The species described as *Tapes laciniata* by Carpenter, 1864, and its Pliocene relative *Paphia (Protothaca) staminea* var. *hannibali* Howe, 1922, are distinct from typical *P. staminea*. The longer pallial sinus, extending more than one half the distance from the posterior toward the anterior end, is a feature which serves to separate the present species from *P. grata* Say, a generally more southern species.

Protothaca (Novacallithaca) euglypta Sowerby, from Japan, is more elongate in outline and the margin bears strong denticulations.

Protothaca kovatschensis Ilyina (952) described from strata of Miocene age in Kamtschatka was compared by its author with *P. staminea*.

Protothaca staminea occurs abundantly in shallow water in bays and inlets often at depths of two or three inches in coarse, sandy, muddy bottoms and on the open coast in sand under cobbles and rocks. The ecology and growth of this species has been discussed by Smith (953).

SUBGENUS *CALLITHACA* DALL

Callithaca Dall, Proc. U. S. Nat. Mus., Vol. 26, No. 1312, p. 364, December 29, 1902.

Protocallithaca Nomura, Saito Ho-On Kai Mus. Res. Bull., No. 13, p. 10, August, 1937. "Genotype: *Venus adamsi* Reeve, 1850." Illustrated pl. 3, figs. 4a, 4b. Japan, Recent. — See also Habe, Gen. Jap. Shells, Pelecypoda, No. 2, p. 180, September, 1951.

Type species (by original designation). — "Type, *Tapes tenerrima* Carpenter."

Range. — Late Miocene to Recent, western North America and Japan. Recent from the intertidal zone to about 46 meters (25 fathoms).

Original description. — Sculpture delicate, uniform over the disk and reticulate except in distorted individuals; lunule feebly defined with no escutcheon; the dorsal margin not overlapping in the right valve; inner margins entire, otherwise as in *Protothaca*. (Dall.)

Remarks. — This subgenus was considered to be of no taxonomic importance by Frizzell, 1935, and Grant and Gale, 1931.

The differences between the type species of *Protothaca* and *Callithaca* may be of only specific value, but the fact that the right valve does not overlap the left posteriorly, the faintly defined lunule, and the smooth inner margins of the valves of *Callithaca* are distinct features. For the present we retain *Callithaca* as a subgenus of *Protothaca*.

Key To Species And Subspecies Of *Callithaca*

A. Posterior end elliptically curved; height 70 to 75 percent of the length . . . . . *tenerrima*

B. Posterior end broadly curved (or subtruncated); height 75 to 80 percent of the length . . . . . (subspecies) *alta*

Protothaca (Callithaca) tenerrima Carpenter
Plate 51, Figures 1-3; Plate 52, Figures 13, 14

Tapes tenerrima Carpenter, Proc. Zool. Soc. London for 1856, p. 200, issued January 7, 1857.

Paphia tenerrima Carpenter, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 173, 182, 1912. "San Diego-Purisima." Lower Pliocene. — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 272, pl. 22, figs. 1a, 1b, 1918. "Range. — Strait of Juan de Fuca, Washington, to San Quentin Bay, Lower California (Dall)."—I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci.,

Vol. 1, p. 156, pl. 30, figs. 1a, 1b, 1924. Various localities cited; range, from Pliocene to Recent.

Protothaca tenerrima Carpenter, Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 65, fig. 31, 1953. "Range: British Columbia to Magdalena Bay, Baja California."

Protothaca (Callithaca) tenerrima Carpenter, K.V.W. Palmer, Geol. Soc. Amer., Mem. 76, p. 97, 1958. [Discussion of Carpenter's species. Type specimen not found.]

Type specimen. — Location unknown to the present authors.

Type locality. — "Hab. Panama; legit Col. Jewett. Mus. Gould." [Carpenter later stated. ". . .*Tapes tenerrima*, Cpr., P. Z. S. July 1856, which is a Californian and not a Panamic species, as had been supposed from Col. Jewett's label". (See Rept. Brit. Assoc. Adv. Sci. for 1863, p. 531, August, 1864.)]

Range. — Late Miocene ("cf."); early Pliocene to Recent. Recent from Vancouver Island, British Columbia, to Cape San Lucas, Lower California, Mexico; beach to 46 meters (25 fathoms). Often in sandy bays and estuaries at depths of 10-16 inches beneath the surface (Fitch).

Occurrence in San Diego Fm. — C.A.S. 957, 1135, 1140, 1178, 1402, 28885, 28886. L.A.M. 104, 305, 305A, 305C. S.D. 21, 417. U.C.L.A. 294.

Original description. — T. t. tenerrima, albido-fusca, obovali, compressa; marginibus aequaliter excurvatis; striulis radiantibus creberrimis, antice et postice fortioribus, et lirulis acutis concentricis, plus minusve distantibus, eleganter ornata; lunula vix stria majore definita; intus, dent. card. iii. radiantibus, quorum valva in altera ii. altera i. bifidi sunt; sinu palii maximo, elongato, lateribus suberectis, parum divergentibus, apice cicatr. ant. contiguo, subrotundato; margine vix crenulato. Long. .94, lat. 1.13, alt. .38. (Carpenter.)

Remarks. — Several specimens, in various states of preservation, are present in the collections from the San Diego Formation. One specimen retaining the anterior portions of both valves came from Loc. 305A (LAM) from near the Mexican boundary. A large left valve from Loc. 305C (LAM) is 126 mm long and 92.5 mm high. The shell characters of the various specimens all appear identical with those of Recent *Protothaca tenerrima.*

Perfect specimens of *P. tenerrima* are easily separable from other west American species of this genus by the elongate, ovate, flattened shell which is sculptured with fine sharp concentric lamellae.

A subspecies, *Protothaca (Callithaca) tenerrima alta* Waterfall, described from strata of Pleistocene age in Ventura Co. California, is comparatively higher in proportion to the length.

Protothaca restorationensis Frizzell (955) described from Pleistocene beds at Puget Sound, Washington, is intermediate in outline between *P. staminea* and *P. tenerrima.* The shell is thicker and the valves are more inflated than the latter species. *Protothaca restorationensis* occurs from Puget Sound to Halfmoon Bay, California. A specimen collected by Mrs. Jack Copsey at Loc. 33901 (CAS), Tom's Point, Bolinas Bay, California, agrees well with paratypes (Nos. 5350, 5351) of Frizzell's species in the series of type specimens in the California Academy of Sciences.

Protothaca (Callithaca) tenerrima alta Waterfall
Text-Figure 12

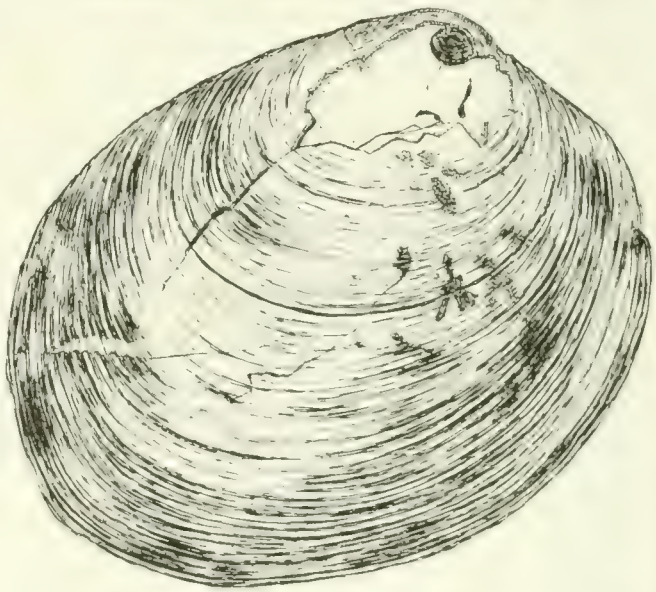
Paphia (Callithaca) tenerrima alta Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, pl. 6, fig. 1, April 6, 1929.

Type specimen. — No. 31418, Invertebrate Paleontology Collection, University of California.

Type locality. — "Saugus, U. C. Loc. 7088, Hall Canyon, two miles northeast of Ventura, California."

Range. — Middle Pliocene to Pleistocene.

Occurrence in San Diego Fm. — L.A.M. 305C.



Text Fig. 12. *Protothaca (Callithaca) tenerrima alta* Waterfall. Hypotype (Los Angeles County Museum), right valve, from Loc. 305C (LAM), near the Mexican boundary, southwestern San Diego County; Pliocene. Length 125 mm. (Drawn by Dorothy Ludlow.)

Original description. — Shell large, relatively thin, oval; beaks strongly prosogyrous, small, situated about one-sixth the distance from the anterior end; dorsal side evenly convex, rising slightly above the beaks; ventral side subtruncate; sculpture consists of more or less evenly spaced, fine concentric ridges which are, in general, spaced about 3 mm apart in the central part of the shell, between which there are, in places, similar but finer lines and faint incremental lines which become more prominent toward the periphery; radial sculpture consists of fine low ridges, less prominent than the concentric lines; and most prominent between the latter; teeth in the left valve (broken in type) three, sharp, the central one bifid; right valve unknown; hinge long, narrow, no lunule or escutcheon; pallial sinus reaching to about one-third the distance from the anterior end.

Dimensions. — Height, 96 mm, length 117 mm, diameter of left valve 25 mm. (Waterfall.)

Remarks. — A right valve 125 mm long and 103 mm high, a left valve 125 mm long and one specimen with both valves, are here assigned to *Protothaca (Callithaca) tenerrima alta.* The right valve, relatively higher in proportion to the length of typical *P. (C.) tenerrima* and

with a broadly rounded (nearly subtruncated) posterior end, is typical of the subspecies. The left valve is less typical but appears to be referable to this subspecies. A smaller specimen from the same locality is 93 mm long, 71 mm high, the convexity (both valves together) 33 mm. The posterior end of this fossil is more steeply sloping than specimens of typical *P. (C.) tenerrima* of comparable size.

The shell characters which serve to distinguish this subspecies from the typical form are more apparent on large adults than on juvenile specimens.

GENUS IRUSELLA N. GEN.

Irus of west American authors.

Not *Irus* Oken, 1815, nor *Irus* Schmidt, 1818.

Type species. — *Venus lamellifera* Conrad, 1837.

Range. — Aquitanian, early Miocene, to Recent. Recent from low tide to about 65 meters (35 fathoms).

Description. — Shell small to moderate size (40 mm long), ovate, roundly truncated posteriorly, moderately convex; sculptured with elevated, slightly reflexed, concentric lamellae which are separated by smooth interspaces 3 to 4 mm wide, and on the early portions of the valves, by fine radial striae; lunule small, ovate, crossed by the concentric lamellae; ligament external, sunken below edge of dorsal margin. Hinge plate narrow, four teeth in each valve, the anterior one smallest, the left middle and right middle and posterior ones with a slight median groove; ventral margin finely denticulated; posterior muscle impression the larger; pallial sinus extends forward a little less than half the length of the shell, roundly pointed at the end.

Remarks. — The west American species described as *Venus lamellifera* by Conrad has been placed in the genus *Irus* Oken (956) by some authors. Oken's usage of that generic name is not available because the publication in which it appeared was ruled invalid for purposes of nomemclature by the Internat. Comm. Zool. Nomencl. in 1956, Opinion 417. Keen (957) called attention to this ruling and suggested that *Venus lamellifera* be placed in *Notirus* Finlay (958). The type species of that genus, *Venerupis reflexa* Gray, is sculptured with numerous fine, low, concentric lamellae and, on the specimens which we have examined, there is almost no circumscribed lunule and the early portion of the shell lacks radial striae.

Recently, Bowden and Heppell (Jour. Conch., Vol. 26, No. 4, p. 260, 1968) called attention to and accepted the usage of *Irus* Schmidt (Versuch. Conchyl. — Samml., p. 158, 1818) with the type by tautonomy, *Donax irus* Linnaeus.

The new genus here proposed, *Irusella*, is similar to *Paphonotia* Hertlein and Strong (959), but it differs from that genus in the much thicker shell, coarser concentric lamellae, the radial sculpture confined to the early portion of the shell and the ventral margin of the interior denticulated rather than smooth. The species of this genus live in holes in rocks or in empty shells or in holes which it forms by burrowing in soft rocks. The shape is extremely variable.

Irusella lamellifera Conrad
Plate 50, Figure 11

V[enus]. lamellifera Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 251, pl. 19, fig. 19, 1837.

Petricola cordieri Deshayes, Rev. Zool., Soc. Cuvierienne, Année 1839, p. 358 (December, 1839). "California, dans les marnes calcaires, où elle se creuse des trous profonds." — Deshayes, Mag. de Zool., Livr. 6, Moll., pl. 18, 3 figs., 1840.

Venerupis lamellifera Conrad, I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 160, pl. 39, fig. 8, 1924. Monterey to San Diego, California, Recent.

Irus lamellifer Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 332, pl. 18, figs. 5a, 5b, 6a, 6b, 8, 1931. Pliocene to Recent. — Abbott, American Seashells (D. Van Nostrand Co., Inc.: New York), p. 412, pl. 31, fig. 3, 1954 (as *Irus lamellifera).* Monterey to San Diego, California.

Type specimen. — Location of type specimen unknown to the present authors.

Type locality. — "Inhabits the coast of California, with the preceding. Very rare; a single valve only was found." [The preceding species is "*V. californiana.* Sby." from "Inhabits the coast of California, in muddy marshes near Sta. Diego."]

Range. — Late Miocene to Recent. Recent from Shelter Cove, Humboldt Co., to San Diego, California (960), from low tide to 65 meters (35 fathoms).

Occurrence in San Diego Fm. — U.C.L.A. 298.

Original description. — Shell suboval, compressed; disks with about eight lamelliform concentric slightly reflected ribs, and very obscure radiating sulci; posterior extremity widely truncated; colour white; pallal impression with a profound sinus. (Conrad.)

Remarks. — A single right valve, length 27.3 mm, height, 24 mm, convexity, 12 mm, from Pliocene strata at Pacific Beach, is present in the collections of the University of California at Los Angeles. The umbonal portion and the hinge are lacking and the concentric lamellae are more irregularly spaced than typical forms of this species. This form is well within the variation of *Irusella lamellifera* resulting from its habit of boring in soft rocks or nestling in pre-existing cavities.

A large left valve of this species from San Miguel Island, California, in the Henry Hemphill collection in the California Academy of Sciences, is 42.5 mm long.

A variety of this species of Miocene age, described by Grant and Gale (961), was said to differ from typical *Irusella lamellifera* in the more widely separated concentric lamellae and more circular shape.

Petricola cordieri Deshayes, 1839, is a synonym of *Irusella lamellifera.* Records of "*Venerupis*" *cordieri* from Port Alfred, South Africa, are referable to *Venerupis multicostata* Turton (962).

GENUS *PSEPHIDIA* DALL

Psephis Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 536, 611, 640, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 22, 97, 126, 1872. — Carpenter, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, p. 56, April, 1865.

Not *Psephis* Guenée, 1854. Lepidoptera.

Psephidia Dall, Jour. Conch., Vol. 10, No. 8, p. 243, October 1, 1902. New name for *Psephis* Carpenter,

1864, not *Psephis* Guenée, 1854. — Dall, Proc. U. S. Nat. Mus., Vol. 26, No. 1312, p. 366, December 29, 1902. "Type: *Psephis lordi* Baird." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 336, 1931. Type as indicated by Dall. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 313, 1961. "Type species by original designation, *Psephis lordi* Baird."

Type species (subsequent designation for *Psephis* by Carpenter, 1865). — "Exemplum typicum: *Psephis Lordii = Chione Lordii*, Proc. Zool. Soc., 1863, p. 69." Same designated for *Psephidia* by Dall, 1902.

Range. — Middle Pliocene to Recent. Recent from about 9 to 91 meters (5 to 50 fathoms).

Description. — Shell small, veneriform, polished, with faint sculpture; beaks not prominent; valves inequilateral, with a narrow, feebly defined lunule and no escutcheon; inner margins not crenate; pallial sinus distinct, angular; hinge with three delicate entire cardinals in each valve, but no laterals; animal with the mantle edges fused below, the siphons short, simple; an anterior opening for the foot, which is not byssiferous.(Dall, 1902.)

Remarks. — Five species of *Psephidia* have been recorded from strata of Pliocene and Pleistocene age in California and a like number have been recorded living in west American waters between Unalaska, Alaska, to the Gulf of California. Three of these are known to be viviparous.

Key to Species of *Psephidia*

A. Valves smooth, with lines of growth only . . . . . *ovalis*

B. Valves sculptured with concentric ridges . . . . . *stephensae*

Psephidia ovalis Dall
Plate 47, Figures 5, 9; Plate 51, Figures 8, 9

Psephidia ovalis Dall, Proc. U. S. Nat. Mus., Vol. 26, No. 16, fig. 4, December 29, 1902. — Dall, U. S. Nat. Mus., Bull. 112, p. 44, 1921. Range: St. Paul Island, Bering Sea, to San Diego, California. — I. S. Oldroyd, Standford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 161, pl. 34, fig. 4, 1924. [Same range as given by Dall.] — J. Q. Burch (editor), Min. Conch. Club South. California, No. 42, p. 16, fig. (p. 17), December, 1944. Range as given by Dall. (See also Viola S. Bristol, No. 52, p. 35, 1945.) — Abbott, American Seashells (D. Van Nostrand Co., Inc.: New York; Toronto; London), p. 411, fig. 82c [not 82b=*P. lordi*], 1954. [Copy of Dall's illustration.]

Psephidia lordi Baird variety *ovalis* Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 337, 1931. Pliocene to Recent. — Faustman, Univ. Calif. Publ. Geol. Sci., Vol. 41, No. 2, p. 121, 1964 (as *Psephidia lordi* Baird subsp. *ovalis*). Rio Dell Formation; Elk River Formation; Scotia Bluffs Sandstone; Merced Formation; Etchegoin Formation.

Type specimen. — No. 163089, United States National Museum.

Type Locality. — "North side of Catalina Island, California, in 16 fathoms gravel and sand; W. H. Dall."

Range. — Middle Pliocene to Recent. Recent from St. Paul Island, Bering Sea, to San Diego, California, 29 to 91 meters (16 to 50 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305C.

Original description. — Shell small, white, polished, oval, subcompressed; surface with obsolete concentric threads near the anterior base, but over most of the disk smooth; beaks small and very low, at about the anterior third of the length; lunule elongated, extremely narrow, nearly as long as the anterior dorsal slope; escutcheon linear or none; interior white, the pallial sinus moderate, pointed; internal margin delicately straited; hinge well developed, like that of *P. lordi*, with three entire cardinals and no anterior lateral tooth. Length, 8.5; height, 6.5; diameter, 3.0 mm. (Dall.)

Remarks. — Two small valves and one larger one (5.5 mm long) in the collection from near the Mexican boundary are referred to *Psephidia ovalis*. These valves are not as ovate as the original illustration of the type specimen. However, considerable variation is observable among individuals in a series of Recent specimens. Dr. Myra Keen compared the valves from the San Diego Formation with Recent specimens of *P. ovalis* in the collection at Stanford University and considers the fossil valves to be definitely referable to this species.

Some authors have considered this form to be a subspecies of *P. lordi* Baird (963) but in many recent works it is accorded specific status.

Psephidia stephensae n. sp.
Plate 44, Figures 21, 22, 24, 26

Description. — Shell small, rounded triangular, the beaks slightly anterior of the center, lunule and escutcheon only slightly developed; exterior with well developed, slightly irregular, concentric sculpture, the ridges rounded in the early stage but flattened on the later stage of the valves; hinge with three cardinal teeth, the central one the larger and slightly grooved; interior smooth, margins with two or three faint concentric grooves; muscle impressions typical of the genus; ligamental area small. Length of holotype 3.0 mm, height 2.7 mm.

Type specimens. — Holotype, a right valve, and paratypes a right and a left valve (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM), at the same elevation; fossils in float slump and consolidated boulders, silt and sandstone, and silt in place. San Diego Formation, Pliocene, [Loc. 305 (LAM) is 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian].

Range. — Middle Pliocene to Recent. Recent from off Santa Rosa Island, California, to San Hipolito Point, Lower California, Mexico, also Guadalupe Island, and Cedros Island, in 16 to 88 meters (9 to 48 fathoms).

Occurrence in San Diego Fm. — L.A.M. 319.

Remarks. — A number of specimens, mostly single valves, of this species are in the collection of the Los Angeles County Museum from near the Mexican boundary.

Variation in proportion of length to height can be observed in a series of specimens. Some are more highly

trigonal than others.

This new species resembles *Psephidia cymata* Dall (964) but differs chiefly in lacking an anterior lateral tooth in the left valve. Dall did not mention this feature of the hinge in the original description of his species. Woodring (1941), p. 95) mentioned the presence of "a short anterior lateral lying close to the anterior cardinal" on Dall's species and A. M. Keen (written comm.) noticed a similar tooth on a paratype of *P. cymata* in the collection in Stanford University. The presence of a left anterior lateral is a characteristic feature of *Transennella* (separating it from *Psephidia*) and on this basis Dall's species should be assigned to that genus.

Recent specimens reported under the name of *Psephidia cymata* from off Guadalupe Island (Hanna and Strong, Proc. Calif. Acad. Sci., Ser. 4, Vol. 19, No. 1, p. 6, 1930) and from off Cedros Island (Hertlein and Strong, Zoologica, Vol. 33, pt. 4, p. 193, 1948), appear to be identical with the new species described here.

A fossil cited as "*Psephidia* n. sp. ?" was reported by Woodring (965) from strata of Pliocene age in San Joaquin Valley. It resembles "*Psephidia*" *cymata* Dall but is smaller, more trigonal, and lacks an anterior lateral tooth. The shape is much more highly trigonal than the new species from San Diego.

The shell of *Psephidia salmonea* Carpenter (966) is generally more elongated and the concentric sculpture is much finer and more closely spaced than that on *P. stephensae* n. sp.

This species is named for Mrs. Kate Stephens, former Curator of Marine Invertebrates, San Diego Society of Natural History.

[*Psephidia barbarensis* Arnold]

Psephidia barbarensis Arnold, Smithsonian, Misc. Coll. (Quarterly Issue), Vol. 50, Pt. 4, No. 1781, p. 440 (22), pl. 58, fig. 3, December 13, 1907. — Arnold, U. S. G. S., Bull. No. 321, p. 32, pl. 12, fig. 3, 1907. "Fernando formation, Bath-house Beach, Santa Barbara," "Fernando (Pliocene)." — Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, table opp. p. 78, 1929. "San Diego Pliocene."

Type specimen: Holotype No. 165,238, United States National Museum.

Type locality: "Bath-house Beach, Santa Barbara, California."

Range. —? Middle Pliocene (Waterfall), to late Pliocene or early Pleistocene.

Occurrence in the San Diego Formation. — "San Diego Pliocene" (Waterfall).

Remarks. — The only record of *Psephidia barbarensis* from the San Diego Formation is that of Waterfall. Dr. E. C. Allison and Mr. Joseph Peck, Jr., searched for but failed to find the specimen or specimens in the collections of the University of California upon which Waterfall's record was based. We have not noticed this species in any of the collections which we have studied from the San Diego Formation.

According to Arnold the diagnostic features of this little venerid are, "This species is higher and more trigonal in outline, has a straighter anterior margin, and a less conspicuous anterior tooth than *P. lordi* Baird, which it resembles."

Keen and Bentson (967) stated that *Psephidia barbarensis* is probably identical with *Venus rhysomia* Gabb (968), described from strata at Santa Barbara, California, but the type material of Gabb's species was not detected by them.

GENUS *TRANSENNELLA* DALL

Transennella Dall, Proc. U. S. Nat. Mus., Vol. 6, p. 341, 1883 (issued January 4-9, 1884). Sole species, "*Cytherea (Transennella?) conradiana* n. s." — Dall, Proc. U. S. Nat. Mus., Vol. 26, No. 1312, p. 348, 1902. "Type, *T. conradiana* Dall." p. 367, pl. 13, fig. 6 [not fig. 5 as stated on p. 411], 1902. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1240, October, 1903. "Type *T. conradiana* Dall. Florida." — Hertlein and Strong, Proc. Calif. Acad. Sci., Ser. 4, Vol. 23, No. 24 p. 376, 1939. Type by monotypy.

Type species (by monotypy). — *Cytherea (Transennella?) conradiana* Dall, 1884, p. 340. "Habitat. — Rare at Cedar Keys, in mud between tides." [Illustrated by K. V. W. Palmer, Palaeontogr. Americana, Vol. 1, No. 5, p. 302 (94), pl. 47, (16), figs. 4, 8, 10, fig. 10 in text, 1927. Florida, Pleistocene and Recent. — Abbott, American Seashells (Van Nostrand Co., Inc., New York), p. 413, fig. 83c, 1954. "South half of Florida and the Bahamas", Recent.]

Range. — Early Miocene to Recent. Recent in Atlantic and Caribbean from Florida to the West Indies; in the Pacific from Sitka, Alaska, to Chile, from the intertidal zone to about 91 meters (50 fathoms).

Description. Shell small, trigonal, with lively coloration; smooth and polished or concentrically striate; hinge with three cardinals in each valve, the middle left cardinal bifid; an elongated anterior lateral in the left valve, received in a sulcus in the right valve; lunule defined by an incised line, escutcheon not defined; nymphs without rugosities; pallial sinus angular, free below, obliquely ascending; internal margins of the valves sharply tangentially grooved with numerous sulci. (Dall, 1903.)

Remarks. — The presence of an anterior lateral tooth in the left valve serves to separate *Transennella* from *Psephidia*. The presence of strong oblique grooves on the margins of the valves is generally considered to be a characteristic feature of *Transennella*.

Species referred to this genus have been reported only from the Atlantic and Pacific coasts of the Americas. The Atlantic species, typical of the genus as mentioned by several authors, possess a deeper pallial sinus, the oblique grooving on the interior ventral margin is stronger and so far as known, they are not viviparous.

In California, *Transennella joaquinensis* Anderson and Martin was described from Temblor beds of middle Miocene age, *T. californica* Arnold was described from strata of Pliocene age, and *T. tantilla* Gould has been reported with doubt from beds of late Miocene age and definitely from late Pliocene to Recent. *Transennella herviderana* Spieker was described from beds of Miocene age in Peru, and *T. galapagana* Hertlein and Strong was

recorded from a raised beach deposit of Pleistocene age, also Recent, in the Galápagos Islands. Five species referred to *Transennella* live in west American waters in the region between Sitka, Alaska, and Chile. The species described as "*Psephidia*" *cymata* by Dall may be referable to *Transennella.*

Transennella tantilla Gould
Plate 44, Figures 20, 23, 25, 27

Venus tantillus Gould, Boston Jour. Nat. Hist., Vol. 6, p. 406, pl. 15, fig. 10, October, 1853.
Transennella tantilla Gould, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 338, pl. 15, figs. 8a, 8b, 1931. Pleistocene and Recent.

Type specimen. — "Half figured holotype" No. 169391, Museum of Comparative Zoology, Harvard University (Johnson, U. S. Nat. Mus., Bull, 239, p. 156, 1964).

Type locality. —"Inhabits Santa Barbara. Col. Jewett."

Range. — ?Middle Miocene; middle Pliocene to Recent. Recent from Sitka Harbor, Alaska, to Lat. 27° S., Lower California, Mexico, littoral zone to 36.5 meters (20 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305A, 309, 318. U.C.L.A. 1386.

Original description. — Shell quite small, rather solid, ovate-trigonal, inequilateral; beaks acute, surface smooth or faintly waved with distant concentric furrows; the dorsal margins are nearly straight, and meet at the apex in a right angle, but the posterior side is a fourth longer than the anterior; the anterior basal angle is well rounded, while the posterior is acute; basal margin gently curved. Color white, but the posterior third is stained deep slaty blue outside and in, the line of demarcation being quite abrupt and well defined; there is also a pencil of the same color inside, running from the beak to the anterior cicatrix; the rest of the interior is cream colored. (Gould.)

Length one fourth of an inch; height one fifth of an inch. (Gould.)

Remarks. — A series of specimens of this species varying in size from 2 to 7 mm in length are in the collections from San Diego and from near the Mexican boundary. The largest one is a left valve 7 mm long and 6 mm high. Large Recent specimens attain a length of 8 mm.

These specimens agree with Recent shells in shape, sculpture, and hinge. There are three cardinal teeth in each valve and in the left valve there is an anterior lateral tooth. A lanceolate lunule below the beaks is bounded by a faintly incised line. The outline of the pallial sinus on the fossils is similar to that on Recent specimens, short, rounded at the end and directed toward the anterior impression. The interior ventral margin is grooved.

"*Transennella* cf. *T. tantilla* (Gould)" (969) was recorded from the middle part of the Altamira Shale member of the Monterey Shale probably of middle Miocene age in Los Angeles Co. Specimens, possibly *T. tantilla*, were found in Pliocene strata in the Santa Maria district. According to Woodring (970) those fossils are smaller and have a thinner shell than Recent specimens of *T. tantilla.*

Transennella tantilla was recorded by Martin (971) from the Merced Formation of late Pliocene age, near San Francisco, California. In a later paper Martin (972) cited it only from the "Upper Merced" of Pleistocene age. It also has been recorded from strata of late Pliocene age in the Los Angeles area.

A small venerid in the upper Etchegoin and in the San Joaquin Formation in the San Joaquin Valley, was referred by Stewart (973) to "*Transennella* cf. *T. tantilla* (Gould.)" He suggested that *Transennella californica* Arnold (974) is probably identical with *T. tantilla.* Woodring (1950, p. 90), however, stated that the type specimen of *T. californica* has a more inflated umbo than that of the Recent shalls of *T. tantilla.*

Hansen (975) discussed the brooding habits and other features of living *Transennella tantilla.*

FAMILY PETRICOLIDAE D'ORBIGNY (976)

Shell elongate to subglobose, variable in shape on account of the habit of boring in clay or soft rock, or nestling in holes in rock or in other shells; gaping at both ends; hinge narrow, with two or three cardinal teeth in each valve, of which one or more may be bifid, the posterior cardinal tooth generally small; ligament external, attached to a coarse posterior nymph; sculpture consisting of radial ribs and fine concentric lamellae which may be nearly obsolete; pallial sinus usually extending to the middle of the valve. (Adapted from Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 354, 1931 and Olsson, Mollusks of the Tropical Eastern Pacific Paleo. Res. Inst.: Ithaca, New York, p. 314, 1961.)

Range. — Cretaceous to Recent.

Remarks. — This family is represented in the Cenozoic of western North America by one genus and three subgenera.

GENUS *PETRICOLA* LAMARCK

Petricola Lamarck, Syst. Anim. s. Vert., p. 121, 1801. Species cited: "*Petricola sulcata.* n. *Venus lithophaga.* Retz. In Act. Acad. Taurin. vol. 3, p. 11." "*Petricola costata*, n. *Venus lapicida*, Chemn. Conch. 10, p. 356, t. 172, f. 1664, 1665. An *Donax irus.* Linn." "*Petricola striata.* n." — Gardner, U. S. G. S., Prof. Paper 199-A, p. 116, 1943 (issued January, 1944). Type as designated by Schmidt.

Type species (by subsequent designation, Schmidt, Versuch Conchyl.-Samml., pp. 55, 176, 1818). — "Type *Venus lapicida.* X. Fig. 1664, 1665." [Chemnitz, Syst. Conchyl. Cab., Bd. 10, p. 356, Tab. 172, figs. 1664, 1665, 1788. In "Corallsteinen gefunden, dergleichen einige Schiffer bey den Westindischen Zuckerinsuln als Ballast im untersten Schifsraum eingeladen hatten". Illustrated by Warmke and Abbott, Caribbean Shells (Livingston Publ. Co.: Narberth, Pennsylvania), p. 191, pl. 44, fig. e, 1961 (as *Petricola lapicida* Gmelin).]

Range. — Eocene (Keen); Recent, widely distributed in temperate and tropical waters, from the intertidal zone to 82 meters (45 fathoms).

Description.– Shell thin, oval or elongate, often irregular, gaping. Umbones anterior but not terminal. Lunule ill defined. Sculpture dominantly radial and in the genotype divaricate or zigzag. Inner margins smooth. Ligament external, attached to nymphs. Armature of right valve usually consisting of two cardinals, the posterior of which is grooved or bifid; third rudimentary cardinal rarely present; left valve furnished either with three divergent cardinals (the middle one bifid, the remaining two simple) or with two divergent cardinals (a simple posterior and a bifid anterior); laterals absent in the normal adult. Pallial sinus narrow, as a rule, and ascending, with considerable variation in depth. (Gardner, 1948.)

This is a nestling or burrowing genus, which exhibits the variability of dwellers in such a habitat. (Gardner, 1948.)

Remarks. — One species of *Petricola* was described from strata of late Miocene age in Contra Costa Co. and two species have been reported from beds of Pliocene age in southern California. One species is known to occur in the San Diego Formation. About a dozen species and varieties of this genus have been described from west American waters in the region between California and northern Peru. About 25 species, widely distributed, are now living in temperate and tropical seas.

Warmke and Abbott mentioned that the divaricate pattern on the exterior of the type species, *Petricola lacipida*, is only a calcareous coating on the surface of the shell and is not sculpture.

SUBGENUS *RUPELLARIA* FLEURIAU DE BELLEVUE

Rupellaria Fleuriau de Bellevue, Jour. Phys., Vol. 54, p. 347. Species cited: "Repullaire striée" and "Rupellaire reticulée" "*Venus lithophaga.* Retz." — Gardner, U.S.G.S., Prof. Paper 199-A, p. 116, 1943 [January, 1944]. "Type by elimination: *Venus lithophaga* Retzius."

Type species (designated by Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1058, 1900). — "Type *P. lithophaga* (Retzius)." [Mem. Acad. R. Sci. Turin, Vol. 3, Mém des Corresp., pp. 11, 14, figs. 1, 2, 1786. Illustrated by Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillion, Vol. 2, Fasc. 9 (Pelecypoda, Fasc. 22), p. 445, pl. 67, figs. 20-25; 26-28 (var. *striata*), 1893. For synonymy and discussion of this species see Lamy, Jour. de Conchyl., Vol. 67, No. 4, pp. 323-328, 1923, Mediterranean, Adriatic, and Atlantic from Strait of Gibralter to England.]

Range. — Eocene to Recent

Description. — Shell short, inflated anteriorly, more compressed and attenuated posteriorly; radial sculpture usually present over entire shell but coarser anteriorly; pallial sinus broadly rounded at the end.

Remarks. — West American species which generally have been referred to *Petricola s. s.* are referable to the subgenus *Rupellaria* as mentioned by Keen. (977).

Petricola (Rupellaria) carditoides Conrad
Plate 44, Figures 15, 16

S[axicava]. carditoides Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 255, pl. 20, fig. 8, 1837.

S[axicava]. californica Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 256, pl. 20, fig. 9, 1837. "Inhabits California near Sta. Barbara and Sta. Diego."

Petricola carditoides Conrad, Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 274, pl. 20, figs. 6a, 6b, 1918. San Francisco Bay region, from between tides to a depth of 45 fathoms. — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 50, pl. 42, figs. 6a, 6b, 1924. [Illustrations same as those of Packard.] San Juan Island, Washington. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci. Vol. 1, p. 163, pl. 34, figs. 6a, 6b, 1924. [Illustrations same as those of Packard.] "Bolinas", California. Range: Vancouver Island to Lower California. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 355, pl. 13, figs. 14a, 14b, 1931, various localities, Pliocene to Recent.

Type specimen. — Location of type specimen unknown to the present authors.

Type locality. — "Inhabits California near Sta. Barbara, where a single valve only was collected."

Range. — Pliocene to Recent. Recent from Vancouver Island, British Columbia to Scammon's Lagoon, Lower California, Mexico, from the littoral zone to 82 meters (45 fathoms).

Occurrence in San Diego Fm. — L.A.M. 107, 305. U.C.L.A. 294.

Original description. — Shell oblong - oval; disks with minute radiating lines; ligament margin straight, parallel with the basal margin; posterior extremity direct; cardinal teeth prominent. Length, an inch and a half (Conrad.)

Remarks. — An elongate left valve of this species in the collection of the University of California at Los Angeles, is 30 mm long, and 15.7 mm high, convexity, 7.8 mm. Much of the sculpture on the exterior is eroded but fine radial threads are visible on the anterior portion of this specimen. It agrees in every way with specimens of Recent *Petricola carditoides.*

A few poorly preserved specimens from Loc. 107 (LAM) are referable to *P. carditoides* and a fragment of a right valve from Loc. 305 (LAM), from near the Mexican boundary is probably referable to this species.

The shape of the shell of *Petricola carditoides* is exceedingly variable, from elongate to rounded in outline, as a result of its habitat in holes in rocks, or in other shells. The sculpture of the exterior is often almost obliterated on some fossils. Four varietal forms of this species were cited by Lamy (978).

Petricola pedroana Conrad (979), originally described from beds of Pleistocene age at San Pedro, California, is now generally placed in the synonymy of *P. carditoides.*

Petricola lucasana Hertlein and Strong (980) described from "Cape San Lucas, Lower California, Mexico", is a similar species but differs in the slightly coarser radial riblets and in the different coloration of the shell. The interior of the tropical form is blackish-brown and the exterior dark orange-brown in comparison to the nearly white shell of *P. carditoides.*

Petricola buwaldi Clark (981), described from late Miocene strata in central western California, is allied to *P. carditoides* and *P. lucasana* but possesses much coarser radial riblets. Two species, comparable to *P. carditoides*

and *P. buwaldi*, respectively, were reported by Woodring as occurring in strata of Pliocene age in the Santa Maria region.

Yonge (982) gave an excellent discussion of the occurrence and habits of Recent *Petricola carditoides*. He concluded that this species usually settles in some pre-existing cavity which, by mechanical means, the animal enlarges to exactly fit the valves when open. The siphons extend into the water.

SUPERFAMILY TELLINACEA OKEN (983)

A discussion of the structure and adaptations of the Tellinacea has been published by Yonge (984).

FAMILY TELLINIDAE OKEN

Shell rounded anteriorly, more or less rostrate, obliquely truncated and gaping posteriorly; valves slightly unequal, compressed, margins usually smooth, beaks small, sculpture usually concentric; anterior adductor impression sometimes the larger; resilium subexternal; hinge plate with small cardinals and with or without laterals; pallial sinus usually long, sometimes discrepant on the two valves. Jurassic (985) to Recent.

This family is represented in the San Diego Formation by three genera. Dall's (986) useful synopsis of the Recent west American species has been supplemented by a compilation of the Recent species by Salisbury (987). Many of the tropical and subtropical west American species have been discussed by Hertlein and Strong (988), Keen (989), and Olsson (990). Papers by Boss (991) deal with the subfamily Tellinae in the western Atlantic.

Key to Genera of Tellinidae

A. Hinge usually with lateral teeth; exterior often shiny . . . . . *Tellina*

B. Hinge lacking lateral teeth; exterior often dull

- a. Elongate to subtrigonal; posterior end produced and narrowed; moderately compressed . . . . . *Macoma*
- aa. Suborbicular to subtrigonal; subequilateral; broad median depression in right valve; strong siphonal fold; moderately inflated . . . . . *Florimetis*

GENUS TELLINA LINNAEUS

Tellina Linnaeus, Syst. Nat., ed. 10, p. 674, 1758. *Tellina radiata* Linnaeus included among species cited. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 357, 1931. Type as designated by Children, *Tellina radiata* Linnaeus. — Gardner, U. S. G. S., Prof. Paper 199-A, p. 94, 1943 [January, 1944]. Type as designated by Schmidt, *Tellina radiata* Linnaeus.

Type species (designated by Schmidt, Versuch Conchylien-Sammlung, pp. 51, 177, 1818). — "Typ. *Tellina radiata.*" Same species also cited by Children, Quart. Jour. Sci. Lit. Arts, Vol. 14, p. 306, pl. 5, fig. 46, 1823. [*Tellina radiata* Linnaeus, Syst. Nat., ed. 10, p. 675, 1758. "Habitat in Oceano Europaeo." Illustrated by Reeve, Conch. Icon., Vol. 17, *Tellina*, sp. 8, pl. 3, figs. 8a, 8b, 1866. "Hab. West Indies." — Boss, Johnsonia, Vol. 4, No. 45, p. 235, pl. 129, figs. 1-4; pl. 130, fig. 1, 1966. Florida to the Guianas, South America. — Afshar, Geol. Soc. Amer., Mem. 119, p. 24, pl. 1, figs. 1-5, 1969. See discussion of this species by Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 45, 1952.]

Range. — Early Cretaceous to Recent. Recent from the intertidal zone to 1170 meters (640 fathoms).

Description. — Shell elongately oval to ovately trigonal; compressed, often rostrate or twisted posteriorly; beaks low; porcelaneous; surface smooth or chiefly concentrically sculptured; ligament external, opisthodetic; hinge with small cardinals and usually two laterals in each valve; pallial sinus well developed, often partly confluent with the pallial line.

Key to Subgenera of *Tellina*

A. Shell with course concentric sculpture

- a. Two lateral laminae in both left and right valve . . . . . *Tellinella*
- aa. One or both lateral laminae lacking or obsolete in left valve . . . . . *Peronidia*

B. Shell with fine concentric sculpture or smooth.

- a. Two lateral laminae in left and right valve . . . . . *Tellina s. s.* (992)
- aa. One or both lateral laminae lacking or obsolete in left valve.
  - b. Valve with internal raised radial ridge behind anterior muscle impression . . . . *Oudardia* (993)
  - bb. Valves lacking internal raised radial ridge behind anterior muscle depression.
    - c. Pallial sinus confluent with pallial line for nearly entire length . . . . . *Moerella*
    - cc. Pallial sinus only partly confluent with pallial line . . . . . *Cadella*

SUBGENUS *TELLINELLA* MÖRCH

Tellinella Gray, Mörch, Cat. Conch. Yoldi, Fas., 2, p. 13, 1853. Species cited include *T. antoni* Phillippi, *T. interrupta* Solander, *T. pulchella* Lamarck, *T. rostrata* Linnaeus, *T. virgata* Linnaeus, and several others. — Hertlein and Strong, Zoologica, Vol. 34, Pt. 2, p. 64, August 10, 1949. Type as designated by Stoliczka.

Type species (designated by Stoliczka, Mem. Geol. Surv. India, Paleont. Indica, Ser. 6, Cretaceous Fauna of South India, Vol. 3, pp. XVII, 116, 1871. — *Tellina virgata* Linnaeus [Syst. Nat., ed. 10, p. 674, 1758. "Habitat in O. Indico." Illustrated by Hanley, Thes. Conch., Vol. 1, p. 228, pl. 63, fig. 212, 1846. Indian Ocean. — Afshar, Geol. Soc. Amer., Mem. 119, p. 25, pl. 2, figs. 1-5, 1969.]

Range. — Cretaceous to Recent.

Description. — Shell with strongly rostrate posterior end and concentric sculpture consisting of sharp, elevated lamellae.

Remarks. — This subgenus is represented by several species in the Tertiary strata of California. At the present time only two species occur off California, and two occur in tropical and subtropical west American waters. Other Recent species occur in warm Atlantic and Indo-Pacific waters.

Fleming (994) placed *Maoritellina* Finlay in the synonymy of *Tellinella.*

Tellina (Tellinella) idae Dall
Plate 53, Figures 6, 11

Tellina idae Dall, Proc. U.S. Nat. Mus., Vol. 14, No. 849, p. 183, pl. 6, fig. 3; pl. 7, figs. 1, 4, July 24, 1891. Long Beach and Catalina Island, California, Recent. Also "Fossil in the Miocene of San Diego, California." — Williamson, Proc. U. S. Nat. Mus., Vol. 15, No. 898, p. 185, 1892. Dall's record of San Diego occurrence cited. — Cooper, Calif. State Min. Bur., Bull. No. 4, p. 32, 1894. "Mioc.? — San Diego, Dall." — I.S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 164, pl. 14, fig. 4, 1924. [Reproduction of Dall's (1891) pl. 6, fig. 3] — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 358, pl. 20, fig. 12 (middle Pliocene over the Newhall railroad tunnel, Los Angeles Co.), 14a, 14b (Upper San Pedro of Santa Monica), 1931. Dall's record, "Miocene" at San Diego cited. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 84, 1929. "San Diego Pliocene". — Abbott, American Seashells (D. Van Nostrand: New York), p. 422, figs. 28h, 87a, 87b, 1954. Santa Monica to Newport Bay, California.

Type specimen. — No. 120098, United States National Museum.

Type locality. — "Habitat: Long Beach, San Pedro California."

Range. — Middle Miocene (Temblor Formation) to Recent. Recent from Santa Barbara Islands to San Pedro and Long Beach, California, in 37 to 91 meters (25 to 50 fathoms).

Occurrence in San Diego Fm. — C.A.S. 1401. L.A.M. 107, 305, 305A, 318, 319. S.D. 27, 29. U.C.L.A. 2359.

Original description. — Shell ovate - triangular, moderately elongate, white, compressed; exterior of the right valve slightly flatter, and with more prominent sculpture than the left valve; beaks small, pointed, prominent, laterally compressed, adjacent to each other; anterior part of the shell slightly longer than the part posterior to the beaks, evenly and regularly oval, the dorsal and basal curves almost identical; posterior dorsal slope steeper, rectilinear, obliquely truncate at its termination, the basal curve (behind the perpendicular from the beaks) similar to its anterior part as far as the flexure, which is narrow but well marked, its basal end moderately incurved; behind, it rises to a strong ridge the end of which forms a rostral projection, behind which, in the right valve, is a deeply impressed line a little in advance of the posterior dorsal margin, which is strongly compressed; on the left valve there are two lines with a narrow impressed area between them, above which the dorsal margin is swollen; in front of the beaks is a narrow, acute, deeply excavated, short lunule; behind the beaks is a large, narrow, still more excavated escutcheon, most of which is excavated from the left valve, which falls short of the right valve a little; the ligament is sunken in and about half as long as the escutcheon; it is quite invisible on a lateral view of the shell; the left valve is regularly, sharply, closely, concentrically grooved, and both are obsoletely, finely, radiately striate; the margin between the impressed area of the left valve and the escutcheon is more finely grooved than the rest and has a (somewhat irregularly) denticulate dorsal edge; the right valve has the concentric sculpture more distant and, ventrally, shows distinctly elevated narrow lines with wider interspaces regularly disposed, and also bears denticulations on its posterior dorsal margin; the umbones are nearly smooth; the shell gapes but little, chiefly at the end of the rostrum; internally the surface of the valves is smooth, the muscular and pallial impressions are brilliantly polished; besides the usual marks, in the specimen under examination there are, near the posterior ventral angle of the pallial sinus, two small circular impressions and some obscure and irregular markings at the entrance of the sinus, all due, doubtless, to attachments of the mantle and probably inconstant or variable in different individuals; the anterior part of the pallial sinus nearly reaches the scar of the anterior adductor, and nearly the whole of the basal part is coincident with the line of the basal attachment of the mantle; the hinge plate is broad and subtriangular, quite strong, bearing one prominent grooved tooth between two channels; behind the posterior channel, in the left valve, is a much narrower, obscure, and little - raised tooth; the corresponding second tooth in the right valve is anterior and similarly obscure; the left valve is destitute of lateral teeth, but in the right valve there is a short, strong, elevated, subtriangular; anterior lateral close to the anterior cardinal, and a more distant and feeble posterior lateral over the posterior adductor scar. Altitude of shell, 28.5; maximum longitude, 48; diameter, 8.5 millimeters, of which 5.0 millimeters is comprised in the left valve. (Dall.)

Remarks. — This species is represented in the present collections by three nearly complete single valves and by a number of small ones and fragments of valves. The largest is a left valve from Loc. 305A (LAM), near the

Mexican boundary, 65.8 mm long, height (incomplete) 38.4 mm. A right valve, complete except for the extreme posterior end, is 57 mm long, 33 mm high, and convexity 6 mm. An impression of the larger portion of a right valve from Loc. 1401 (CAS), from the south slope of Mount Soledad, is 58 mm long (incomplete) and 34.6 mm high.

The shell of this species is characterized by the strongly rostrate posterior end and the well-developed, raised, sharp, concentric sculpture. These concentric threads are spaced a little less than 1 mm apart on the medial portion of an adult right valve. Burch (995) pointed out that young specimens of this species are equilateral and triangular in shape with coarser sculpture than on adults.

Tellina nevadensis Anderson and Martin (996) was placed in the synonymy of *T. idae* by Grant and Gale. The specimens in the type lot of *T. nevadensis* are large, a paratype is 72 mm long. The type specimens are higher in proportion to the length in comparison to specimens of *T. idae*. Perhaps differences in details of the two are a result of size and preservation.

Tellina idae was recorded occurring in Temblor beds of middle Miocene age by Loel and Corey, and by Stewart (997). The latter author cited "*Tellina* cf. *T. idae* Dall" from the Temblor Formation and a species under this same caption was listed by Woodring (998) from the middle part of the Altamira Shale member in Palos Verdes Hills, near San Pedro, California, in beds probably of middle Miocene age, and later (1950, p. 98) he cited it from the Cebada Member of the Careaga Sandstone (Pliocene). Moore (999) recently reported "*Tellina* aff. *T. idae* Dall" from the Astoria Formation of middle Miocene age in Oregon.

A similar species is *Tellina tenuilineata* Clark (1000) which was described from near Walnut Creek, California, in beds believed to be of Oligocene age.

Tellina englishi Clark (1001) described from beds of late Miocene age is another similar species. Judging from casts of the type specimen, the shell is more elongated than that of *T. idae*. However, it may fall within the variation of the Recent species as suggested by Grant and Gale.

That *Tellina idae* may be recorded under more than one name in the literature referring to the fauna of Miocene strata appears quite possible, for Loel and Corey (1002) cited *T. idae*, *T. tenuilineata* and *T. tenuistriata* Davis (1003), all from the "Temblor Horizon."

Tellina idae has been recorded from several localities from beds of Pliocene or Pleistocene age in southern California; at San Quintín, Lower California; and by Durham from beds of late Pliocene age in the Gulf of California.

SUBGENUS *CADELLA* DALL, BARTSCH, AND REHDER

Cadella Dall, Bartsch, and Rehder, Bernice P. Bishop Mus., Bull. 153, p. 196, July 25, 1938. "Type: *Tellina lechiogramma* Melville." — Habe, Gen. Jap. Shells, Pelecypoda, No. 3, p. 212, 1952. "Type species: *Tellina lachiogramma* Melville (original designation.)"

Type species (by original designation). — "*Tellina lechiogramma* Melville" [*Tellina (Maera) lechriogramma* Melville, Mem. Proc. Manchester Lit. Philos. Soc., Ser. 4, Vol. 7, No. 1, p. 65, pl. 1, fig. 22, 1893. "Hab. Bombay (Abercrombie)." India. — Afshar, Geol. Soc. Amer., Mem. 119, p. 33, pl. 8, figs. 6-10, 1969. "Karachi, Pakistan."]

Range. — Late Miocene to Recent. Recent from northern Lower California to Japan, India, and South Africa.

Original description. — Shell small, broadly ovate to donaciform, rather inflated, the valves comparatively thick, white or grayish or tinged with rose. The umbones are located a third to a fourth of the entire length from the posterior end, from which the posterior margin may descend rather sharply to an obtuse, postero-ventral angle, or the posterior end may be somewhat longer and rounded; anterior to the umbones is a long slender depressed lunule. The sculpture consists of fine, closely concentric ridges, which flatten out anteriorly so that the sculpture there appears to consist of fine, evenly separated grooves. Ligament rather short, situated in a broadly lanceolate escutcheon. The hinge is typically tellinid, the left anterior and right posterior cardinal teeth being stout and triangular, with or without a slight groove; the right anterior cardinal is usually rather well developed and lamellar, while the left posterior cardinal is short and rather thin; the laterals in the right valve are well developed, while those in the left valve are fused with the margin. Interior white or suffused with pink; muscle scars suborbicular, the posterior one slightly smaller than the anterior one. Pallial sinus rather large and broad, slightly ascending, the basal margin only partly fused with the pallial line. (Dall, Bartsch, and Rehder.)

For the present *Cadella* might be placed near *Moerella*, which differs not only in shape and sculpture, but also in having a larger sinus, which is almost completely fused ventrally with the pallial line, and a larger right posterior lateral which is more closely approximated to the cardinal teeth than in *Cadella*. (Dall, Bartsch, and Rehder.)

Remarks: Dall, Bartsch, and Rehder pointed out that *Cadella* differs from *Semelangulus* Iredale (1004) in possessing an external ligament.

Cadella includes several small ovate species reported only from the Pacific and Indian Ocean. It is reported from late Miocene to Recent in California, Pliocene to Recent in Japan, and Recent in Hawaii, India, and South Africa.

Tellina (Cadella) salmonea Carpenter
Plate 53, Figures 2, 3, 4, 8, 16

Maera salmonea Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 627, 639, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 113, 125, 1872. — Carpenter, Ann. Mag. Nat. Hist., Ser. 3, Vol. 14, p. 423, December, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 235, 1872. "Hab. San Francisco (Pac. Rail. E.E.); Neeah Bay (Swan), plentiful; Monterey, 20 fathoms (Cooper)."

Tellina (Moerella) salmonea Carpenter, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 157, pl. 13, fig. 7, 1903. "Pleistocene. — San Pedro (Arnold)." "Living. — Van-

couver to Monterey (Carpenter)". — K.V.W. Palmer. Geol. Soc. Amer., Mem. 76, p. 105, pl. 13, figs. 17-19, 1958. Aleutian Islands, Alaska, to San Pedro, California. Also Pleistocene.

Tellina salmonea Carpenter, Packard, Univ. Calif. Publ. Zool, Vol. 14, No. 2, p. 276, pl. 25, figs. 3a, 3b; pl. 46 (map), 1918. Within San Francisco Bay and west of the Golden Gate, in 6¼ to 17 fathoms. — I.S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 165, pl. 44, figs. 3a, 3b, 1924. (Under subgenus *Moerella*) [Same figures as given by Packard, 1918.] "Aleutian Islands to San Pedro, California." Recent.

Type locality. — Indicated as from "Neighbourhood of S. Francisco"; "Vancouver Island, Straits of S. Juan de Fuca, and adjoining Washington Territory"; "Neighbourhood of Monterey" (Carpenter, August, 1864). "Recent. Neah Bay, Washington, Vancouver Island region (type)" (K.V.W. Palmer).

Range. — Late Miocene (Cierbo Formation) to Recent. Recent from the Aleutian Island, Alaska, to South Coronado Island, Lower California, Mexico, usually on a sand bottom, from the intertidal zone to 154 meters (84 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A, 319.

Original description. — Small, subquadrate, glossy, salmon-tinted. Beach-20 fm. (Carpenter, August, 1864.)

Supplementary description. — M. testa parva, solida compacta, subquadrata; laevi, nitente, epidermide tenui cinera induta; extus pallide, intus vivide salmonea tincta; marginibus dorsalibus rectis, ad angulum 120° separatis, umbonibus haud extantibus; marginibus antico et ventrali regulariter late excurvatis; parte postica brevissima, haud angulata, intus,dent. card, utraque valve ii., quorum unus bifidus; lateralibus v. dextr. aequidistantibus, ant. extant, post. parvo; nymphis rectis, haud conspicuis; cicatr. add. post. subrotundata, ant. subrhomboidea; sinu palii satis regulariter ovali, per iv. inter v. partes interstitii porrecto. Long. .57, lat. .45, alt. .11 poll. (Carpenter, December, 1864.)

Variat testa aurantiaca, rarius albida, rosaceo tincta. (Carpenter.)

Remarks. — About 50 single valves of this little species were collected by G. P. Kanakoff near the Mexican boundary. The largest valve is 10.3 mm long and 8 mm high. A large Recent left valve from Seven Mile Beach, San Francisco, is 14.4 mm long and 12 mm high. The pallial sinus extends in an even ellipse to about 9.9 mm from the posterior end, does not touch the anterior adductor impression and slopes posteriorly to join the pallial line at about 7 mm from the posterior end of the valve. Fresh specimens are usually tinted with the salmon coloration characteristic of this species.

The record of *Tellina solmonea* from beds of Pliocene age in Japan given by Kanehara (1005) was later referred to *Cadella lubrica* Gould by Hatai and Nisiyama (1006).

Tellina kesenensis Nomura and Hatai (1007) a Recent species in Japanese waters, compared by its authors with *Tellina salmonea*, was referred by Habe (1008) to *Cadella lubrica* Gould. *Tellina (Peronidia) solmonaeformis* Nomura and Hatai (1009) has a larger, higher shell which is more trigonal in outline than that of *T. salmonea.*

[SUBGENUS *OUDARDIA* MONTEROSATA]

Oudardia Monterosata, Nomencl. Gen. Spec. Conch. Medt., p. 22, 1884, "II tipe è la *Tellina Oudardi*, Payr." — Cossmann and Peyrot, Act. Soc. Linn. Bordeaux, Vol. 66, (Conch. Néog. 1, Aquitaine, Tome 1. Livr. 2), p. 263, 1910. " (G. - T. *Tellina compressa* Br. Viv.)," text. fig. 38, and pl. 10, figs. 21-25. — K.V.W. Palmer, Geol. Soc. Amer., Mem. 76, p. 102, 1958. "Type species by original designation, *Tellina oudardi* Payraudeau, . . . "

Type species (by original designation). — *Tellina oudardi* Payraudeau [Moll. Corse, p. 40, pl. 1, figs. 16-18, 1826. "Hab. Figari, Santa-Giulia, Favone. Rare." — Hanley, Thes. Conch., Vol. 1, p. 297, pl. 66, fig. 262, 1846 (1847). According to Monterosata this species includes *Tellina compressa* Brocchi (Conch. Foss. Subapp., Vol. 2, p. 514, pl. 12, fig. 9, 1814. "Fossile in Valle de Andona." See figs. 14, 15, 16, 1901); Ronchetti, Rev. Ital. Paleo. e strat., also Sacco, Moll. Piemonte e Liguria, Pt. 29, p. 111, pl. 23, Mem. 5, Pt. 1, p. 85, fig. 35 (holotype), 1952].

Range. — Early Eocene to Recent.

Description. — Shell small, thin, ovoid, beaks situated at about two-thirds the distance from the anterior end of the valves; one anterior lateral adjacent to the cardinals; a well developed radial ridge is present just behind the elongated anterior muscle impression; exterior sculptured with fine concentric lines of growth.

Remarks. — This subgenus has been recorded from Pliocene to Recent in western North America. However, a careful study of fossil Tertiary forms in this region may reveal the presence of *Oudardia* in beds of an earlier age.

Boss (1010) recently placed *Oudardia* in the synonymy of *Angulus* Megerle von Mühlfeld. Fourteen species living in the western Atlantic were assigned to the latter subgenus.

[*Tellina (Oudardia) modesta* Carpenter]

Angulus modestus Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 602, 639, 681, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 88, 125, 167, 1872. — Carpenter, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, p. 56, 1865 [as (Tellina) *Angulus modestus.*] [Full description.]

Not *Angulus modestus* Verrill. 1872.

Tellina modesta Carpenter, Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11, (later Tertiary deposits of San Diego), p. 27 [lower bed (A), San Diego Peninsula]. 1878.

Not *Tellina modesta* Sowerby, Proc. Zool. Soc. London, January, 1883, p. 31, pl. 7, fig. 1, "Hab. Port Jackson (Brazier)."

Mera modesta Carpenter, Cooper, Calif. State Min. Bur. Seventh Ann. Rept. State Mineral., p. 250, 1888. "Pl. — San Diego well."

Tellina (Oudardia) modesta Carpenter, K.V.W. Palmer, Geol. Soc. Amer., Mem. 76, p. 103, pl. 13, figs. 4-9, 1958. (Type specimens illustrated.)

Type specimen. — Syntypes No. 4245, United States National Museum. (Palmer.)

Type locality. — Indicated as "Puget's sound and the

neighborhood" (Carpenter, 1864); "Hab. in sinu Pugetiano, specimina duo juniora legit Kennedy" (Carpenter, 1865). "Recent. Puget Sound, Washington (type)." (Palmer, 1958.)

Range. — Pliocene. Pleistocene and Recent. Recent, Vancouver Island, British Columbia, to Lower California. (Dall.)

Original description. — "Like *tener*, Say; but with callus between mantle-bend and scar. White." (Carpenter, 1864.)

Remarks. — The only definite record of *Tellina modesta* in the San Diego Formation is that of Cooper. We have seen no specimens in any of the collections from that area. It was cited by E.K. Jordan as occurring in beds of late Quaternary age in San Ignacio Lagoon, Lower California. Also reported by Valentine from Timms Point Silt, lower Pleistocene, from north border of Palos Verdes Hills, Los Angeles Co., California. It appears to be rare in most collections of Recent shells.

SUBGENUS *MOERELLA* FISCHER

Donacilla Gray, List. Brit. Anim. Brit. Mus., Pt. 6, p. 39, 1851.

Not *Donacilla* Lamarck, 1819.

Moera H. and A. Adams, Gen. Rec. Moll., Vol. 2, p. 396, 1856.

Not *Moera* Huebner, 1819, Lepidoptera.

Moerella Fischer, Man. de Conchyl., Fasc. 11, p. 1147, June 15, 1887. Sole species, *Tellina donacina* Linnaeus. —Cossmann and Peyrot, Act. Soc. Linn. de Bordeaux, Tom. 64 (Conch. Néogén. de l'Aquitaine, Tome 1, Livr. 2), p. 224, 1910, "(G.-T.: T.: donacina L. Viv.)" fig. 30. — Gardner, U.S.G.S., Prof. Paper 199-A, p. 94, 1943. Type by monotypy: *Tellina donacina* Linnaeus. — Hertlein and Strong, Zoologica, Vol. 34, Pt. 2, p. 67, 1949. "Type (by monotypy); *Tellina donacina* Linnaeus." — Olsson and Harbison, Acad. Nat. Sci., Philadelphia, Monogr. No. 8, p. 125, 1953. "Type by monotypy: *Tellina donacina* Linné. Recent, coast of Europe and the Mediterranean."

Type species (by monotypy). — *Tellina donacina* Linnaeus [Syst. Nat., ed. 10, p. 676, 1758. "Habitat in M. Mediterraneo." Ref. to Gualtieri, Test., pl. 88, fig. N. 1742. — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 12 (Pelecypoda, Fasc. 25), p. 648, pl. 91, fig. 12, 14 (typical) and 15-19 vars., March, 1898. Mediterranean; also other localities. — Keen, Treatise Invert. Paleontology, Pt. N. Vol. 2, Moll. 6, p. N618, fig. E107, 7 a-d, 1969. "Eu. — N. Am. Pac." — Afshar, Geol. Soc. Amer., Mem. 119, p. 33, pl. 8, figs. 1-5, 1969. Exmouth, England. Also from North Sea to Mediterranean. For a discussion of this species see Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 48, 1952].

Range. — Early Eocene to Recent. Recent west American species live at depths of 5 to 128 meters (3 to 70 fathoms), and perhaps deeper.

Description. — Shell rather small for the genus, transversely ovate, obscurely rostrate posteriorly. Sculpture dominantly concentric, the Recent species often rayed with colors. Umbones low, opisthogyrate. Lunule and escutcheon extremely narrow, indicated but not well defined. Ligament external, opisthodetic. Two cardinal teeth in each valve, the anterior right and the posterior left simple and laminar, the posterior right and the anterior left stouter and bifid. True laterals not developed in the left valve, though the edges are beveled to function as laterals and are received within the lateral sockets on the right valve; the anterior lateral more elevated and closer to the umbo than the posterior. Pallial sinus confluent ventrally with the pallial line throughout the greater part of its extent. (Gardner, 1943.)

The pallial sinus extends anteriorly near to the anterior adductor impression.

Remarks. — There have been differences of opinions among authors concerning the subgeneric assignment of some west American species, whether to *Angulus* Megerle von Mühlfeld, 1811, or to *Moerella* Fischer, 1887. Gardner, 1943, and Olsson and Harbison, discussed these subgenera and assigned species from the western Atlantic, formerly placed in *Angulus*, to *Moerella*. More recently, Boss (Johnsonia, Vol. 4, No. 46, p. 300, 1966) discussed the dentition of the hinges of the type species of those two subgenera and returned to earlier authors' usage of *Angulus* to include many west Atlantic species.

The hinge of *Tellina lanceolata* Gmelin, the type species of *Angulus*, lacks a well developed posterior lateral tooth in the right valve whereas the right valve of *T. donacina*, the type species of *Moerella*, has a well developed lateral tooth.

The subgeneric assignment of some west American species including *T. carpenteri* seems open to question. We have followed the practice of Dall, Olsson, and Keen, in assigning *T. carpenteri* to *Moerella*. However, it is possible that additional studies may result in placing this species in *Angulus* or possibly in a new subgenus with this or a similar west American species as type.

Eames (1011) expressed the opinion that *Moerella* should be replaced by *Psammotaea* Lamarck (Hist. Nat. Anim. s. Vert., Vol. 5, p. 516, July, 1818), with the type species (selected by Children in 1823), *Psammotaea donacina* Lamarck with the type locality, "Habite l'océan d'Europe." This interpretation of *Psammotaea* has not been generally accepted. Keen, in the Treatise on Invertebrate Paleontology, placed *Psammotaea* in the synonymy of *Gari* Schumacher.

Tellina (Moerella) carpenteri Dall
Plate 53, Figures 1, 7, 15; Plate 56, Figure 14

Angulus variegatus Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 611, 627, 639, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 97, 113, 125, 1872. — Carpenter, Ann. Mag. Nat. Hist., Ser. 3, Vol. 14, p. 423, December, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 235, 1872. "Hab. Neeah Bay (Swan); Monterey and Catalina Island, 20-60 fathoms, rare (Cooper)."

Not *Tellina variegata* Gmelin, Linn., Syst., Nat., ed. 13, p. 3237, 1791.

Tellina (Angulus) carpenteri Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1210, pp. 303, 320, November 14, 1900. "This is the *Angulus variegatus* Carpenter, 1864, not *Tellina (Angulus) variegata* Gmelin, 1792."

Tellina (Moerella) carpenteri Dall, K.V.W. Palmer, Geol. Soc. Amer., Mem. 76, p. 104, pl. 13, figs. 12-16, Dec. 8, 1958. Earlier records cited.

Type specimen. — "Syntypes. — U. S. National Museum, no. 15467 (one double and one single left valve)." (K.V.W. Palmer.)

Type locality. — Originally indicated as from "Vancouver Island, Straits of S. Juan de Fuca, and adjoining shores of Washington Territory, formerly known as "Oregon"; "neighbourhood of Monterey" and "the Sta. Barbara Group." "Type locality, either Neah Bay, Washington, or Catalina Island, California." (K.V.W. Palmer.)

Range. — Middle Pliocene to Recent. Recent, Forrester Island, Alaska (Dall), to Concepcion Bay, east coast of Lower California, in 27 to 137 meters (15 to 75 fathoms).

Occurrence in San Diego Fm. — L.A.M. 107, 305, 305A, 318, 319. S.D. 4.

Original description. — "Shape of *obtusus:* no callus; rayed with pink and yellow. 20-60 fm. Cpr." (Carpenter, August, 1864.)

Supplementary description. — *A.* testa form a *A. obtuso* simili, sed costa interna omnino crente, valde inaequilaterali, solidiore, nitente, rosaceo et flavido subradiatim eleganter variegata; striis incrementi concentricis, postice extantioribus; umbonibus postice flectentibus, obtusis: parte antica prolongata, regulariter excurvata; marginibus dorsali et ventrali subparallelis, subrectis; parte postica curtiore, subangulata: intus, dent. card. utraque valve ii, minutis, quorum alter bifidus; v. dext. dent. lat., ant. curto, satis extante, post. nullo; nymphis curtis, latis, parum concavis, subito sectis, valvis postea subalatis; sinu palii fere cicatr. ant. tenus porrecto. Long. .72, lat. .42, alt. .15. (Carpenter, December, 1864.)

Remarks. — This species is represented in the collections by many single valves, most of which came from localities near the Mexican boundary. The hinge and the pallial sinus agree with those of Recent specimens of *Tellina carpenteri.* The pallial sinus ascends from the posterior adductor impression to a rounded point then slopes anteriorly forming an elliptical end which does not quite touch the anterior adductor impression, then slopes posteriorly a short distance and joins the pallial line.

There is variation in the outline of this species as was indicated by the specific name originally assigned to this species by Carpenter. Many specimens agree exactly with typical *T. carpenteri,* other large ones approach in outline the more quadrate form, *T. arenica* Hertlein and Strong (1012) a generally more southern form which may be a southern subspecies of the present one. Some specimens bear a general resemblance to *Tellina (Oudardia) buttoni* Dall but they lack the narrow elevated ridge on the interior of the anterior portion of the valves of that species.

SUBGENUS *PERONIDIA* DALL

Peronidia Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1210, p. 291, November 14, 1900. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1014, December, 1900.

Type species (by original designation). — "Type, *Tellina albicans* Gmelin (*nitida* auct.)." [Linn. Syst. Nat., ed. 13, Vol. 6, p. 3238, 1791. No locality cited. Ref. to "Gault. test. t. 77. f. H?" and "B (Gault. test. t. 77. f. M?" For illustration of *Tellina nitida* Poli see Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 12 (Pelecypoda, Fasc. 25), p. 660, pl. 93, figs: 1-5, 1898. Recent, Mediterranean and west Africa. — Afshar, Geol. Soc. Amer., Mem. 119, p. 84, pl. 35, figs. 1-5, 1969.]

Range. — Eocene to Recent.

Description. — Shell without laterals, having the internal character of *Angulus s. s.,* and the external character of *Eurytellina.* (Dall.)

Remarks. — This subgenus has been reported occurring in widely separated areas in the world. In Europe it has been recorded from the Eocene, and from the Aquitanian (early Miocene) to Recent, and in the same region the type species (1013) of *Peronidia* has been recorded occurring from Helvetian, middle Miocene, to Recent.

In addition to the occurrence of *Peronidia* from late Oligocene or early Miocene to Recent in western North America, and apparently the same distribution in Japan, it also has been reported occurring in beds of Miocene age in New Zealand.

Tellina (Peronidia) bodegensis Hinds
Plate 53, Figures 9, 18

Tellina bodegensis Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, p. 67, pl. 21, fig. 2, 1844 (January, 1845 on cover). — Weymouth, State Calif. Fish Game Comm., Fish Bull. No. 4, p. 42, pl. 11, fig. 1, 1920. Range. "throughout California." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 168, pl. 44, fig. 5, 1924. Earlier records cited. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 362, pl. 20, fig. 13, 1931. Earlier records cited. — Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 73, fig. 39, 1953. "Queen Charlotte Islands, British Columbia, to Cape San Lucas, Baja California."

Tellina (Peronidia) bodegensis Hinds, Burch, Min. Conch. Club South. Calif., No. 43, p. 8, January, 1945. Discussion and earlier records.

Type specimen. — Holotype No. 74.12.11.372, British Museum (Natural History) (Keen, Veliger, Vol. 8, No. 4, p. 267, 1966).

Type locality. — "Inhab. Russian Bodegas. From seven fathoms, on a sandy floor."

Range. — Pliocene to Recent. Recent from Queen Charlotte Islands, British Columbia, to Cape San Lucas, Lower California, Mexico, below low tide level to 27 meters (15 fathoms). "Found on most sandy beaches along the outer coast and particularly in the coarse, shifting sand near the entrances to bays, lagoons, and estuaries." (Fitch.)

Occurrence in San Diego Fm. — L.A.M. 305A. U.C.L.A. 312.

Original description. — Testâ transversâ, oblongâ, albâ, nitidâ, concentricè striatâ; latere antico majusculo, elongato, rotundato, postico nasuto, ad extremitatem truncato, ab umbonibus subprominulo; liris acutis, versus umbones respectantibus; ligamento subinterno. (Hinds.)

Remarks. — A left valve of this species from Loc. 305A (LAM), near the Mexican boundary, is 51.6 mm long and 25.8 mm high. A right valve from Loc. 312 (UCLA), also from near the Mexican boundary, is 37.8

mm in length. These valves agree in all observable shell characters with Recent valves of *Tellina bodegensis*. The pallial sinus on the smaller of the two valves extends to within 3.5 mm of the anterior muscle impression. One of the largest specimens of a Recent shell from Morro Bay, California, in the Henry Hemphill collection of the California Academy of Sciences, is 52.3 mm long, 26.4 mm high, convexity (both valves together), 10.9 mm, the pallial sinus extends anteriorly from the posterior margin, 33.9 mm.

Tellina bodegensis differs from *T. santarosae* Dall (1014) in that the shell is thicker, more convex, less equilateral, higher in proportion to the length, the concentric sculpture is less evenly spaced and the pallial sinus is broader.

A form (1015) of *T. bodegensis* from the Sooke Formation, Vancouver Island, British Columbia, of late Oligocene or early Miocene age, closely resembles the Recent species but differs in that the truncated posterior end of the shell is narrower.

GENUS *MACOMA* LEACH

Macoma Leach in Ross's Voy. of Discovery in H. M. S. Isabella and Alexander, Ap. 2, p. LXII, 1819. Sole species, *Macoma tenera* Leach. — Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1210, p. 292, 1900. "Type, *Macoma tenera* Leach (= *Tellina calcarea* Gmelin)." — Grand and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 365, 1931. Type same as indicated by Dall. — Eames, Philos. Trans. Roy. Soc. London, Ser. B, No. 627, Vol. 235, p. 398, June 26, 1951.

Type species (by monotypy). — *Macoma tenera* Leach, 1819, p. LXII. "M. concentrice striolata, epiderme viridescente-lutea. Lat. 76° N., Long. 76° W." [= *Tellina calcarea* Gmelin, Linn. Syst. Nat., ed. 13, Tom. 1, Pars VI, p. 3236, 1791. "Habitat frequentissima in mari islandiam circumfluente, testa tenui." Ref. to "Chemn. Conch. 6. t. 13. f. 136." Reported by Chemnitz from "wohnet in unzaehlbarer Menge an den Ufern von Iszland und der Ferroeischen Eylande."]

Range. — Eocene to Recent. Worldwide. Recent from the littoral zone to 1300 meters (711 fathoms).

Description. — Shell roundly or elongately trigonal in shape, slightly inflated, usually with a well developed posterior flexure; sculpture consisting of lines of growth, or lacking; lateral teeth lacking; pallial sinus well developed, sometimes differing in shape in the two valves.

Remarks. — A number of species of *Macoma* have been recorded from strata of Tertiary age in California, especially from Miocene to Recent. About 15 species have been recorded from beds of Pliocene age. Four species are recorded in the present paper from the San Diego Formation. This genus is represented by numerous Recent species which occur abundantly in boreal west America waters and only a slightly smaller number extend into subtropical waters or are confined to tropical west American waters. Most of the latter are referred to sub-genera which are confined to warm marine waters.

Oinomikado (1016) remarked on the pallial sinus of a number of species of *Macoma* living in Japan.

Key to Subgenera of *Macoma*

A. Posterior area sculptured with granules . . . . . *Macoploma.*

B. Posterior area with concentric striae only
  a. Dorsal margin behind ligament produced upward . . . . . *Rexithaerus.*
  b. Dorsal margin behind ligament not produced upward . . . . *Macoma, s. s.*

SUBGENUS *MACOMA*, S. S.

Description. — Shell subtrigonal, the periostracum conspicuous; usually colorless, or, if colored, without a color pattern; flexure well marked; the pallial sinus coalescent with the pallial line below and often discrepant in the two valves; inhabiting the cooler seas and especially boreal waters. (Dall, 1903.) Eocene to Recent.

Key to Species of *Macoma*, s. s.

A. Pallial sinus in left valve extending to anterior adductor muscle impression
  a. Shell usually 50 to 65 mm. long; pallial sinus in right valve usually slopes anteriorly where joining pallial line . . . . . *nasuta*
  aa. Shell usually exceeding 50 to 65 mm. in length, pallial sinus in right valve usually slopes slightly posteriorly where joining pallial line . . . . . *nasuta kelseyi*

B. Pallial sinus in left valve not extending to anterior adductor muscle impression
  a. Pallial sinus in right valve elliptical . . . . . *elimata*
  aa. Pallial sinus in right valve subtrigonal
    b. Pallial sinus extending to near (2 mm) anterior adductor impression; shell cuneiform in outline . . . . . *inquinata*
    bb. Pallial sinus extending anteriorly about 3/5 the length of the shell; shell elongately ovate in outline . . . . . *acolasta*

Macoma (Macoma) acolasta Dall
Plate 53, Figures 12, 13

Macoma acolasta Dall, West Amer. Sci., Vol. 19, No. 3, p. 21, June 15, 1921. — Dall, Proc. U. S. Nat. Mus., Vol. 66, Art. 17, p. 19, pl. 8, figs. 2, 3, 1925. Original locality cited. — Manager, Johns Hopkins Univ. Stud. Geol., No. 11, p. 290, 1934. San Quintin Bay, Lower California, Pleistocene. — Addicott and Emerson, Amer. Mus. Novitates, No. 1925, pp. 18, 21, 1959. Three miles southeast of Punta Cabras, Lower California, Pleistocene. — Emerson and Chace, Trans. San Diego

Soc. Nat. Hist., Vol. 12, No. 21, pp. 338, 341, May 27, 1959. Tecolote Creek, San Diego, California, Pleistocene.

Macoma moesta (Deshayes) variety *acolasta* Dall, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 371, pl. 14, fig. 7; pl. 20, figs. 4a, 4b, 10, 1931. San Quintin Bay, Lower California, and southwest of Goleta, California, Pleistocene. — DeLong, Trans. San Diego Soc. Nat. Hist., Vol. 9, No. 25, p. 242, opp. p. 244, 1941. Palos Verdes Sand, upper Pleistocene.

Macoma morroensis T. A. Burch, Min. Conch. Club South. Calif., No. 47, p. 33, pl. 2, figs. 46, 47, April, 1945. "from Morro Bay, Calif."

Type specimen. — No. 333113, United States National Museum.

Type locality. — "Pliocene or early Pleistocene of San Quintin Bay, Lower California," Mexico.

Range. — Middle Pliocene to Recent in southern California; Pleistocene in southern California and in northern Lower California; Recent from Bodega Bay to San Diego, California, from the intertidal zone to 73 meters (40 fathoms).

Occurrence in San Diego Fm. — U.C.L.A. 1386.

Original description. — Shell small, inequilateral, inequivalve, posterior end somewhat bent to the right, surface smooth except for faint incremental lines which are stronger on the posterior area; beaks not prominent, nearer the posterior end; both dorsal slopes somewhat arched, anterior end evenly rounded, base slightly arcuate, posterior end very slightly rostrate; left valve more convex; hinge feeble, right valve with two small cardinals, left valve with a single bifid tooth; pallial sinus in the left valve, subovate, reaching a little beyond the middle of the valve, the lower two-thirds coalescent with the pallial line; in the right valve the sinus is almost triangular. Height 12; length 22; diameter 5.6 mm. (Dall.)

Remarks. — This species is represented in the San Diego Formation by a single specimen retaining both valves, length 25.6 mm, height, 15.4 mm. This is the first record of this species in the San Diego Pliocene. It is known to occur at several localities in beds of Pleistocene age.

The present specimen agrees in all particulars with Dall's original illustration of *Macoma acolasta* except that the pallial sinus bends farther anteriorly before joining the pallial line at an acute angle. However, the amount of variation of this feature in Dall's species is unknown. All other shell characters are so similar that we refer the present fossil to *M. acolasta.*

The shell of *Macoma acolasta* differs from that of *M. moesta* Deshayes (1017), an Arctic and boreal species, in that the shell is more elongated and the posterior end bears a gentle but distinct flexure.

Grant and Gale recorded, questionably, the occurrence of *Macoma moesta* in beds of late Pliocene age in San Joaquin Valley, California, but we have not seen specimens.

The illustrations of the type specimen of *Macoma morroensis* T. A. Burch, although not clear in detail, agree with *M. acolasta* in all observable particulars. A paratype, No. 8344, in the collections of the California Academy of Sciences, an immature specimen about 17 mm in length, agrees well with the early stages of development shown in Dall's illustration of *M. acolasta.*

Macoma (Macoma) elimata Dunnill and Coan
Plate 53, Figure 5

Macoma calcarea Gmelin, Dall. U. S. G. S., Prof. Paper 59, p. 126, pl. 14, fig. 8, 1909. "Miocene of Coos Bay, Oregon." [Pliocene] — Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, table opposite p. 78, 1929. Upper Pico Formation, Pliocene. — Cummings, Touring, and Brabb, Calif. Div. Mines Geol., Bull. 181, p. 208, photo 19, No. 2, 1962. San Gregorio Member of the Purisima Formation, San Mateo Co., Calif., Pliocene. — Faustman, Univ. Calif. Publ. Geol. Sci., Vol. 41, No. 2, p. 122, pl. 1, fig. 4, 1964. Humboldt Co., Calif., also other localities, Pliocene.

Not *Tellina calcarea* Gmelin, Linn. Syst. Nat., Tome 1, Pars. 6, p. 3236, 1791.

"*Macoma* sp. nov. =*M. calcarea*, Arnold 1903," Crickmay, Jour. Geol., Vol. 37, No. 7, pp. 624, 627, 628, 631, 1929. Deadman Island, Pleistocene.

Macoma calcarea Gmelin (small var.), A. Clarke, Trans. San Diego Soc. Nat. Hist., Vol. 7, No. 4, table opp. p. 30, 1931. Timm's Point, Pleistocene. — Woodring, Bramlette, and Kew, U. S. G. S., Prof. Paper 207, p. 84, pl. 33, fig. 6, 1946. Timms Point Silt. — Woodring, Vedder, and Trumbull, also Winterer and Durham, U.S.G.S., Prof. Paper 334-H, p. 302, 1962 (as *Macoma* cf. *M. calcarea*). Los Angeles Co., Pliocene.

Not *Tellina calcarea* Gmelin.

Macoma elimata Dunnill and Coan, Nat. Mus. Canada, Nat. Hist. Papers No. 43, p. 1, figs. 1, 2 (a-e), 3, 6, (2a, 2b), December 9, 1968. — Dunnill and Ellis, Nat. Mus. Canada, Nat. Hist. Papers No. 45, p. 15, figs. 4, 2a-d; 9f, January 10, 1969.

Type specimen. — Holotype No. 46070, National Museum of Canada, Division of Mollusks.

Type locality. — "from the north end of Moresby Island, Satellite Channel, Vancouver Island, British Columbia (48° 44′N. by 120° 19′ W.) . . . in silty sand at a depth of 49 meters on 7 June 1967."

Range. — Middle Pliocene to Recent. Recent from Craig, Alaska, to off Redondo Beach, Los Angeles Co., California, in 15 to 476 meters (7 to 260 fathoms), in silty and clayey sand, and sand.

Occurrence in San Diego Fm. — L.A.M. 107. U.C.L.A. 2359.

Original description. — The shell is moderately inflated, reaching its maximum thickness well anterior to the umbos. The umbos are fairly prominent and slightly raised above the dorsal margin. The shell is ovate anteriorly; posteriorly the dorsal margin is straight and steeply sloping. The anterior end is truncate. The periostracum is greenish grey and flaky and is little eroded except around the umbos. The shell is chalky white and is covered with fine, concentric growth lines. The posterior dorsal margin has a flattened, concave escutcheon. The valves are flexed toward the right posteriorly.

The interior is white with a low polish and silky lustre. The pallial sinuses are discrepant, long in the left valve (stopping just short of the anterior adductor scar), much shorter and lower in the right valve. Both pallial sinuses loop back along the pallial line and are confluent with it beneath the umbos. The posterior cruciform

muscle scar occurs near the ventral - posterior tip of the pallial line and divides into two parts, with a small anterior element. The anterior cruciform scar lies immediately ventral to the pallial line. There are two cardinal teeth in each valve. The left anterior and right posterior teeth are projecting and bifid, while the right anterior and left posterior teeth are projecting, lamellar, and fragile. The left posterior tooth is the thinnest and frequently breaks off when the valves are opened. The holotype is 27.2 mm long, 20.7 mm high, and 9.6 mm thick, (both valves).

Remarks.—Two specimens, the larger one 27.2 mm long, from the San Diego Formation, are present in the collections of the University of California at Los Angeles. These are identical with a series of 29 specimens, the largest one 32 mm long, from Loc. 3 (CAS) in strata of Pliocene age at Coos Bay, Oregon, from which beds a specimen was illustrated by Dall under the name of *Macoma calcarea.* One imperfectly preserved specimen from Loc. 107 (LAM) is comparable to *M. elimata.* Specimens cited as *M. calcarea* by Waterfall from the upper Pico Formation in Ventura Co., California, also are referable to *M. elimata.*

Macoma elimata resembles *M. calcarea* Gmelin but differs from that species in the straighter dorsal margin posteriorly and especially in the somewhat flattened or slightly concave escutcheon (see Dunnill and Coan, 1968, figs. 2a-e, and illustrations of *M. calcarea* Gmelin, figs. 2f, 9, 10). It apparently does not attain the size of large specimens of *M. calcarea,* that is, about 33 mm in length in comparison to 50.8 mm. The spermatozoa of Recent specimens of the two also are said to differ.

Madsen (1018) pointed out that specimens of *M. calcarea* from the Atlantic coast of the eastern United States are generally more elongate in outline. This is well shown in Gould's illustration (1019) of "*Tellina proxima*" from that region.

The *Macoma calcarea* group apparently had its origin in the northern Pacific as suggested by MacNeil (1020). Hatai and Nisiyama (1021) reported *M. calcarea* from Japan from strata believed to be of Miocene age and they also mentioned a subspecies, *M. (s. s.) calcarea izurensis* Yokoyama from the Akadaira Formation of Oligo-Miocene age. Another subspecies, *M. calcarea yoko hamaensis* Aoka (1022) was described from the Nakazoto Formation of late Pliocene age. In England, the *M. calcarea* group is reported to make its first appearance in the Red Crag beds, to which many authors assign an early Pleistocene age. Malatesta (1023) recently discussed the occurrence and identification of *M. calcarea* and subspecific forms in the Pleistocene deposits of Italy and adjacent regions.

Two varieties of *Macoma calcarea* from the Arctic were described by Soot-Ryen (1024). An excellent discussion of the variation of the shell and the habitat of *M. calcarea* was given by Odhner (1025) and later by MacGinitie (1026).

The species described as *Tellina albaria* Conrad (see Moore, E., U. S. G. S., Prof. Paper 419, p. 80, pl. 28, figs. 8, 9, 12; pl. 29, fig. 9, 1963), from Astoria, Oregon, of middle Miocene age, are somewhat more elongate in outline, and may be a precursor of *M. elimata. Macoma twinensis* Clark, from beds said to be of late Oligocene age, is another member of this group.

Macoma (Macoma) inquinata Deshayes
Plate 52, Figures 1, 10

Tellina inquinata Deshayes, Proc. Zool. Soc. London for 1854, p. 357 (issued May 16, 1855). — Sowerby, Conch. Icon., Vol. 17, *Tellina,* species 164, pl. 30, fig. 164, 1867. "Hab. Vancouver's Island." Reproduction of Sowerby's figure by Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 367, pl. 20, fig. 5, 1931. Pliocene to Recent.

Macoma inquinata Deshayes, Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 204, 1909. Quillayute Formation, western Washington, Pliocene. Also "Purisima-San Diego." — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 278, pl. 23, Figs. 2a, 2b, 3a, 3b; pl. 24, Figs. 1a, 1b; pl. 48 (map of distribution). 1918."Bering Strait to Monterey, California (Dall)." Recent. — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 54, pl. 32, figs. 2a, 2b, 3a, 3b, 1924. "San Juan Island, Wash." "Bering Strait to Monterey, Calif.; Japan." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 172, pl. 45, figs. 2a, 2b, 3a, 3b, 1924. Pliocene to Recent. (Illustrations same as in preceding reference.) —Salisbury, Proc. Malacol. Soc. London, Vol. 21, pt. 2, p. 85 (in text), pl. 12, fig. 5 (type), 1934. "from the Columbia River."

Type specimen. — British Museum (Natural History) (A.M. Keen, written comm., January 24, 1967.)

Type locality. — "Hab. Columbia." ["from the Columbia River" (Salisbury).]

Range. — ? Late Miocene; Pliocene to Recent. Recent from Bering Strait to San Pedro, California, from intertidal zone to 110 meters (60 fathoms).

Occurrence in San Diego Fm. — L.A.M. 124. U.C.L.A. 1386.

Original description. — T. testa trigona, crassa, solida, depressiuscula, inaequilaterali, sub epidermide squalide fusca albofusca, ferrugineo inquinata, transversim irregulariter striata, intus candida; latere antico late obtuso, subsemicirculari, superne parum declivi; latere postico cuneiformi, attenuato, superne recto et declivi, extremitate oblique truncato, inferne oblique angulato, flexura parum perspicua; ligamento praelongo, incrassato; cardine bidentato, dentibus lateralibus nullis; sinu pallii magno, profundo, superne gibboso, deinde declivi et apice acuto. (Deshayes.)

Remarks. — Two valves of *Macoma inquinata* from Balboa Park in the collections of the Los Angeles County Museum agree in all details with Recent specimens of this species. The larger one, a right valve, is 44 mm long, 32.8 mm high, and the convexity (one valve), 10.2 mm. The portion of the pallial line visible is identical with Recent forms. A Recent large right valve from Unalaska Island, Alaska, in the collections of the California Academy of Sciences, is 65 mm long, 45.6 mm high, convexity (one valve), 12.2 mm.

Two small valves from Balboa Park, San Diego, in the collections of the University of California at Los Angeles, are referred with question to *Macoma inquinata.* The left valve is incomplete, the right one measures, length, 21 mm, height, 16 mm, convexity, 4.2 mm. These compare favorably with juvenile specimens of *Macoma inquinata* except that the pallial sinus on the right

valve extends closer to the anterior adductor muscle impression. There is a possibility that these fossils are referable to the form described from the Etchegoin Pliocene, *Macoma affinis plena* Stewart (1027). The general outline is similar but the shape of the pallial sinus of *M. a. plena* is not well known. We, therefore, provisionally refer the present fossils to the Recent *M. inquinata*. Based on external features these fossils hardly differ from shells of *M. balthica* Linnaeus of the same size.

This is the first record of the occurrence of *Macoma inquinata* in the San Diego Formation but the species is known to occur in beds of Pliocene age elsewhere on the Pacific Coast.

There has been confusion of *Macoma inquinata* with *M. irus* Hanley (1028) which was described without information as to the locality from which it came. Later it was attributed to "Guinea?" by its author. Hanley stated, "Evidently a perforating species, allied to the *Petricola ochroleuca* of Lamarck, the true *Tellina fragilis* of Linnaeus's collection." Salisbury (1029) concluded from a study of type specimens in the British Museum of Natural History that *M. irus* is identical with *M. inquinata* and with the species described as *Tellina contabulata* Deshayes (1030) from Chinese seas, which locality Salisbury believed is erroneous for that species. However, Keen (1031) recently has shown that the west American species should bear the name *Macoma inquinata*. Some records of *Macoma inquinata* from Japan have been assigned to *Macoma anser* Oyama (1032).

Macoma inquinata arnheimi Dall (1033), described from Alaskan waters, has a higher and more rounded shell than the typical form. Faustman, 1964, reported this subspecies from the Rio Dell Formation in Humboldt Co., California.

Macoma inquinata affinis Nomland (1034), described from beds of Pliocene age in San Joaquin Valley, California, attains a larger size than *M. inquinata*, the height is greater in proportion to the length, and the pallial sinus does not extend so close to the anterior adductor muscle impression. This form bears a general resemblance to the Japanese *M. anser* Oyama but the oriental form is more rounded, the pallial sinus in the left valve is more angulated above and in the right valve it is more distant from the anterior adductor muscle impression.

A fossil form cited as *Macoma* aff. *M. inquinata* Deshayes, was reported by Hickman (1035) from beds believed to be of Oligocene age in Oregon.

Macoma (Macoma) nasuta Conrad
Plate 53, Figure 10; Plate 54, Figure 6

T[ellina]. nasuta Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 258, 1837.

Not *Tellina nasuta* Conrad, in J. D. Dana, U. S. Exped. (Wilkes), Vol. 10, Geol., p. 725, October, 1849. Renamed *Tellina subnasuta* by Conrad in 1865.

Macoma nasuta Conrad, Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11, "Later Tertiaries," San Diego; p. 27, "sand bed (B)," San Diego peninsula, 1878. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 163, 1903. "Pacific Beach." and "San Diego (Arnold)," Pliocene. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 171, 181, 1912. "Purisima-San Diego." Pliocene. — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 279, pl. 23, figs. 1a, 1b, 1c, 1d; pl. 49 (distribution), 1918. San Francisco Bay area. Range, Aleutian Islands, Alaska, to Lower California.—I.S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 53, pl. 32, figs. 1a, 1b, 1c, 1d, 1924. (Same illustr. as shown by Packard.) Kodiak Island and Cook Inlet, Alaska, to Scammon's Lagoon, Lower California.—I.S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 174, pl. 45, figs. 1a, 1b, 1c, 1d, 1924. "San Diego," Pliocene. Also other records.—Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, opp. p. 78, 1929. "San Diego Pliocene."—Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 366, 1931. "Middle Pliocene of Pacific Beach, San Diego (Arnold, 1903)." — Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 74, fig. 40, 1952. "Kodiak Island, Alaska, to Cape San Lucas, Baja California," Recent.

Type specimen. — Syntype No. 1861.5.21.158, British Museum (Natural History). (See A. M. Keen, Veliger, Vol. 8, No. 3, p. 170, 1966.)

Type locality. — "Inhabits coast of California near Sta. Diego."

Range. — Oligocene (Loel and Corey); middle Oligocene (Weaver); early Miocene to Recent. Recent from Kodiak Island, Alaska, to Cape San Lucas, Lower California, from intertidal zone to about 46 meters (25 fathoms). "mostly found in heavy mud or muddy sand of sheltered bays, lagoons and estuaries," at depths of four to eight inches beneath the mud (Fitch).

Occurrence in San Diego Fm. — C.A.S. 957, 1178, 1400. S.D. 21, 80.

Original description: Shell ovate, compressed, smooth but not polished; anterior side dilated; posterior side cuneiform, extremity truncated, much above the line of the base; fold carinated on the superior valve; beaks central, slightly prominent; epidermis extremely thin and deciduous, finely wrinkled, brown; palleal impression of the left valve joining the anterior cicatrix at its lower posterior angle. Length, an inch and three quarters. Height an inch and a third. (Conrad.)

Remarks. — A few specimens, none perfectly preserved, were collected in the San Diego Formation. These do not differ from Recent valves of *Macoma nasuta* in adjacent marine waters.

This species occurs without change throughout the latter half of the Cenozoic in western North America. It is characterized by the nearly centrally placed beaks and bent, obliquely pointed, posterior end. The pallial sinus in the right valve extends to the anterior adductor impression but in the left valve it extends anteriorly, then slopes to and coalesces with the pallial line at about two - thirds the length of the shell. This varies, and in occasional specimens the sinus slopes slightly posteriorly before joining the pallial line.

Macoma jacalitosana Arnold (U. S. G. S., Bull. 396, p. 65, pl. 16, fig. 2, 1909 (issued January 15, 1910), described from the Jacalitos Formation of early Pliocene age, in the San Joaquin Valley, California, is a similar form.

A Recent species in Japanese waters formerly cited as *Macoma nasuta* is now referable to *M. tokyoensis* Makiyama (1036). It is smaller and has a differently shaped

pallial sinus than that of *M. nasuta.*

Macoma nasuta was recorded by Kanehara (1037) as occurring in beds of Pliocene age in Japan but it is not among the species from the Cenozoic of Japan cited by Hatai and Nisiyama (1038).

Macoma aomoriensis Nomura (1039) and *M. ishimoriensis* Aoka (1040), described from Miocene beds in Japan, were compared by their authors with *M. nasuta.*

Macoma nasuta also has been recorded from late Tertiary strata in the Schmidt Peninsula, Kamtschatka, by Khomenko and by Slodkewitsch (1041). However, the posterior end shown in illustrations by the latter author is less pointed and the shell is correspondingly more suborbicular in outline than is that of *M. nasuta.*

Macoma nasuta, known as the "bent-nost clam," is used for food along the coast of California. According to Fitch, this clam always lies on the left side and its siphons are extended to the surface for feeding and are freely withdrawn and re-extended to a different spot.

Macoma (Macoma) nasuta kelseyi Dall
Plate 52, Figures 5, 9, 11, 12
Text-Figure 13

Macoma kelseyi Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1052, pl. 49, fig. 7, December, 1900. — Schuchert, Dall, et al., U. S. Nat. Mus., Bull 53, Pt. 1, p. 381, 1905. "Pleistocene. City Park, San Diego, California." — I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 53, 1924. "Known alive only from off Brown Island, Wash., in 3-4 fathoms." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 171, 1924. Earlier locality records cited.

Macoma nasuta kelseyi Dall, Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, pp. 65, 87, pl. 20, figs. 2, 8 (Graciosa Ridge, 2.9 miles south of Orcutt, California), 1950. Also, Balboa Park, San Diego Pliocene.

Type specimen. — No. 147690, United States National Museum.

Type locality. — "Pleistocene of San Diego, California, obtained in the City Park by Dr. R. E. C. Stearns." [Pliocene.]

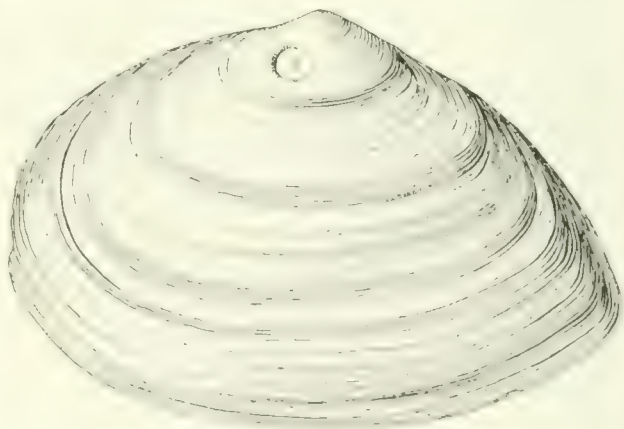
Range. — Middle Pliocene (San Diego Formation; Careaga Formation of Santa Maria district) to Recent. Recent from Puget Sound to Halfmoon Bay, California, (and probably extending over most of the range of *Macoma nasuta),* in 5 to 7 meters (3 to 4 fathoms) and perhaps deeper.

Occurrence in San Diego Fm. — C.A.S. 1402, 1415. L.A.M. 124, 323. S.D. 4, 29, 79, 80, 3206, 5679. U.C.L.A. 302, 1383, 1386.

Original description.—Shell large, solid, heavy, compressed, slightly flexed; beaks subcentral, prominent, pointed; anterior end evenly rounded into an arcuate base and dorsal margin; posterior end lanceolate, the dorsal margin nearly rectilinear; surface sculptured only by strong, rather irregular lines of growth; hinge-plate short, broad, and strong; teeth normal, elongated, large; pallial sinus discrepant in the two valves; left valve with the upper part of the sinus sinuous, extending from the posterior to the anterior adductor, behind which is a thickened, obscure ray; right valve with the sinus short, gibbous, the anterior end rounded, thence the line curves backward before coalescing with the pallial line below; in the left valve the sinus is coincident with the whole of the pallial line below. Long. 86, alt. 56, diam. 20 mm. (Dall.)

Remarks. — A number of paired and unpaired valves of this subspecies are present in the collections from the San Diego Formation. A large valve, from Balboa Park, is 87 mm long, 59 mm high, convexity (one valve), 10.5 mm. The largest specimen in the collections, a right valve from Loc. 124 (LAM), below Snyder's Continuation School, is 106.8 mm long and 77 mm high. The pallial sinus joins the pallial line 75 mm from the posterior end of the valve.

The very large size, thicker shell and slightly bent posterior end are characters included as a basis upon which the present form was separated by Dall as a subspecies of *Macoma nasuta.* Dall also believed that the supspecies *M. n. kelseyi* differed in the character of the pallial sinus in the right valve which he stated bent posteriorly before coalescing with the pallial line. Examination of a number of right valves reveals that there is variation in this character. In some specimens of *M. n. kelseyi* the pallial line does, in others it does not, bend posteriorly before joining the pallial line. Hertlein and Strong (1042) mentioned that this character is variable and considered it open to question whether *M. n. kelseyi* represents a species, subspecies or merely a very large form of *M. nasuta.* The present authors are inclined to the latter view but it is possible that this large form may have ecological or stratigraphic significance and we therefore favor its retention as a subspecies, at least for the present.



Text Fig. 13. *Macoma (Macoma) nasuta kelseyi* Dall. Hypotype (San Diego Society of Natural History), left valve, from Loc. 29 (SD) south of Laurel Street bridge, Balboa Park, San Diego; Pliocene. Length 86.8 mm. (Drawn by E. H. Quayle.)

This subspecies occurs in the Careaga Sandstone, of Pliocene age, in the Santa Maria district and in Pliocene beds at Cedros Island and at Bahía Tórtolo (Turtle Bay), Lower California, as well as at San Diego. Addicott and Emerson (1043) reported this subspecies from beds of Pleistocene age at Punta Cabras, Lower California (Lat.

29° 57′ N.). A Recent large right valve from Halfmoon Bay, California, is 90.8 mm in length. It appears quite probable that this subspecies may occur over much if not all the range of *M. nasuta.*

SUBGENUS *MACOPLOMA* PILSBRY AND OLSSON

Macoploma Pilsbry and Olsson, Proc. Acad. Nat. Sci. Philadelphia, Vol. 93, p. 68, September 9, 1941.

Type species (by original designation). — "Type *Macoma ecuadoriana* new species." [*Macoma (Macoploma) ecuadoriana* Pilsbry and Olsson, 1941, p. 69, pl. 19, fig. 5. "Canoa formation, Punta Blanca," Ecuador, Pliocene.]

Range. — Pliocene to Recent, eastern Pacific. Recent, tropical eastern Pacific.

Original description. — Shell elongate, nearly equivalve, the left valve a little larger and more convex than the right; surface with the granulation of *Periploma*, developed most strongly on the posterior area, finer or absent from the rest of the surface; hinge of *Macoma*, with a small cardinal tooth in the left valve and no laterals. (Pilsbry and Olsson.)

Remarks. — The subgenus *Macoploma* differs from all other subgenera of *Macoma* by the presence of granules on the posterior area and sometimes over the whole shell, similar to *Periploma* and *Thracia.*

The subgenus *Macoploma* is here recorded for the first time from strata of Pliocene age in California. It also is known to occur in strata of Pliocene age in Ecuador and Costa Rica and in sands of late Pleistocene age at San Pedro, California.

Macoma (Macoploma) medioamericana Olsson
Plate 52, Figures 6, 8

Macoma (Macoploma) medioamericana Olsson, Bull. Amer. Paleo., Vol. 27, No. 106, p. 196 (44), pl. 17 (4) fig. 8, December 25, 1942. Cited on p. 242 (90) (as "*Macoma (Macoploma) medioamerciana.*"). — Hertlein and Strong, Zoologica, Vol. 34, Pt. 2, p. 93, 1949. "Arena Bank, Gulf of California, to Panama," in 29 to 82 meters.—Keen, Sea Shells of Tropical West America (Stanford University Press), p. 180, fig. 426, 1958. "The Gulf of California to Panama, intertidally and offshore in depths to 45 fathoms; rare."

Psammacoma (Macoploma) medioamericana Olsson, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 416, 1961. Gulf of California to Panama.

Type specimen. — No. 5004, Paleontological Research Institution, Ithaca, New York.

Type locality. — "Pliocene. Quebrada Peñitas, Costa Rica."

Range. — Pliocene to Recent. Recent from the Gulf of California to Atacames, Ecuador, from intertidal zone to 82 meters (45 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305A.

Original description. — Shell of medium or large size, elongate, delicate; the valves are subequal, the left being slightly larger and more convex than the right which is somewhat flexed or depressed in the middle; beaks, placed at the posterior one-third, are small and pointed; anterior side nearly twice the length of the posterior, obliquely rounded at the end; posterior side somewhat narrowed, obliquely truncated at the end; surface is marked with lines of growth, smoother in the middle, coarse and more or less granulose on the sides; each valve has a narrow, submarginal zone at the posterior end, its surface earthy in appearance and bordered anteriorly by a line of coarse granules; hinge unknown. Length, 62 mm.; height, 30 mm.; diameter, 12 mm. (Olsson.)

Remarks. — A left valve 65 mm long and 32.8 mm high, in the collection from Loc. 305 A (LAM) near the Mexican boundary, agrees in all observable shell characters with *Macoma (Macoploma) medioamericana* Olsson. The shell is somewhat worn but granules are present on the posterior area and along the anterior ventral margin. The pallial sinus on the present specimen is obscured by hard matrix. The hinge bears two cardinal teeth.

The present specimen resembles the illustration of the type specimen of *M. ecuadoriana* described from strata of Pliocene age in Ecuador. *Macoma medioamericana* and *M. ecuadoriana* are similar as pointed out by Hertlein and Strong. According to Olsson the shell of *M. medioamericana* is proportionately longer than that of *M. ecuadoriana* and "It differs also by its coarser, more earthy, or *Thracia*-like granulation of the surface on the posterior submargins." The granulation on *M. ecuadoriana* was originally described as present on the posterior area but fine or lacking elsewhere.

An imperfect left valve of a *Macoma*, 20.6 mm long and 14.4 mm high, from Loc. 305 A (LAM) near the Mexican boundary, is comparable to *Macoma medioamericana* Olsson. No granules are observable on the posterior area but this may be due to erosion of the shell surface. The shape and growth lines agree with a Recent left valve of *M. medioamericana*, 33.3 mm long from Loc. 27557 (CAS) near Punta Arenas, Costa Rica. The hinge of the fossil specimen has a similar grooved anterior cardinal tooth but what was probably the thin posterior cardinal lamella is represented only by a low eroded remnant.

Well preserved specimens of *M. medioamericana* collected by George Kanakoff from sands of late Pleistocene age at San Pedro, California, agree exactly with Recent specimens of that species from the Gulf of California and Central America.

Recent specimens of this species have two cardinal teeth in the hinge of each valve, the posterior tooth usually thinner and more lamellar than the anterior one. The pallial sinus in a left valve 100 mm long ascends rather high to a slightly flattened curve beneath the beak then descends to a rounded point about 68 mm from the posterior end of the valve and then extends posteriorly to where it joins the pallial line about 44 mm from the posterior end of the shell.

SUBGENUS *REXITHAERUS* CONRAD

Rexithaerus Conrad in Tryon, "Catalogue of the family *Tellinidae*," Supl., Amer. Jour. Conch., Vol. 4, No. 5, p. 104, May 6, 1869. Species cited: "*M. secta*, Conrad" (*T. ligamentina*, Desh. in synon.), and "*M. denticulata*, Deshayes" (*T. inaequivalvis*, Sowb. in

synon.). — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1045, December, 1900.

Type species (designated by Dall, Proc. U. S. Nat. Mus., Vol. 32, No. 1210, p. 292, November 14, 1900.) — "Type, *Macoma secta* Conrad." [= *Tellina secta* Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 257, 1837. "Inhabits muddy marshes; Sta. Diego." Illustrated by I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 178, pl. 44, fig. 8, 1924. "Vancouver Island to the Gulf of California. Also Pliocene and Pleistocene. — Weymouth, State Calif. Fish Game Comm., Fish Bull. No. 4, p. 44, pl. 12, figs. 3 and 4; pl. 13, fig. 1, 1920. California coast. — Fitch, same series, Fish Bull. No. 90, p. 75, fig. 41, 1953. "British Columbia to Cape San Lucas, Baja California."]

Range. — Miocene to Recent. Recent from the Gulf of California to Japan.

Description. — Shell large, inequivalve, with a smooth surface, a large and strong deep-set ligament, behind which the dorsal margin is conspicuously produced upward. (Dall, 1900.)

Remarks. — This subgenus is represented in the San Diego Formation by one species and one subspecies. Three species have been cited from the late Tertiary of California.

Key to Species And Subspecies of *Rexithaerus*

A. Beaks on adult specimen about 25 mm. from posterior end; not strongly rostrate posteriorly . . . . . *indentata*

B. Beaks on adult specimen about 30 mm. from posterior end; strongly rostrate posteriorly . . . . . (subspecies) *tenuirostris*

Macoma (Rexithaerus) indentata Carpenter
Plate 52, Figures 3, 4, 7

Macoma Indentata Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 611 ("S. Diego"), 639 (indicated as from "The region between S. Diego and S. Pedro"), issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 97, 125, 1872.—Carpenter, Proc. Calif. Acad. Sci., Vol. 3, p. 208, 1866. "Hab. San Pedro, (young, living, *Palmer*;) large, dead valves, *Cooper*." — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11, "later Tertiary" of San Diego; p. 27, "sandbed (B)" about 12 ft. thick, over Bed (A), San Diego Peninsula, 1878, —Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 161, pl. 16, fig. 1, 1903. Several localities cited, Miocene to Recent. — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 277, pl. 25, fig. 4, 1918. "San Francisco to Lower California," Recent.—I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 55, pl. 41, fig. 4, 1924. (Reproduction of figure given by Packard, 1918.) Recent. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 178, pl. 44, fig. 4, 1924. (Under section *Rexithaerus*). (Reproduction of figure given by Packard, 1918.) "Santa Barbara, California to Lower California," Recent. Also Pliocene and Pleistocene in California.

Macoma (Rexithaerus) indentata Carpenter, K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 109, pl. 16, figs. 1, 2, 1958. (Type specimen illustrated.) "Recent. San Pedro, California (type); Puget Sound, Washington, to Lower California (Dall." Also Miocene to Recent.

Type specimen. — No. 15229, United States National Museum.

Type locality. — "Recent San Pedro, California (type)" (K. V. W. Palmer, 1958.)

Range. — Late Miocene to Recent. Recent from Puget Sound, Washington, to Cholla Bay (1044) in the Gulf of California, Sonora, Mexico, in 15 to 46 meters (9 to 25 fathoms), in sandy mud or in sand.

Occurrence in San Diego Fm. — C.A.S. 1186, 28892. L.A.M. 305, 305A, 319. U.C.L.A. 294, 2359.

Original description: "Like *secta*, jun., but beaked, indented, and ventrally produced." (Carpenter, 1864.) Long. 2.20, lat. 1.40, alt. 0.56 (Carpenter, 1866.)

Remarks.–This species is represented by a few specimens in the collections from the San Diego Formation. The most perfect one, a right valve from near the Mexican boundary, in the collections of the Los Angeles County Museum, is 55.2 mm long and 33.3 mm high. It agrees in all essential shell characters with Recent specimens of this species.

The subspecies *Macoma indentata tenuirostris* Dall is decidedly more elongated than the typical form.

Macoma indentata flagleri Etherington (1045) described from beds of middle Miocene age in western Washington was said to be characterized by the "slightly more prominent beak and the posterior fold is only slightly developed on it as compared with the recent form."

Arnold mentioned a probable relationship between *Macoma indentata* and the species which he described as *Macoma vanvlecki* (1046) from beds of Pliocene age in the San Joaquin Valley. Grant and Gale suggested that Arnold's species was probably but a variety of *M. indentata*. However, an examination of a cast of the type specimen of *M. vanvlecki* shows it to differ from the Recent species as stated by Arnold; namely, in the much longer and much more convex form. The fossil which Nomland (1047) illustrated under the name of *Macoma vanvlecki* from the Etchegoin Formation apparently scarcely differs from Recent *M. indentata* and is not referable to the species described by Arnold.

Grant and Gale suggested the possible identity of *Macoma moliniana* Dall (1048) from Coos Bay, Oregon, with *M. indentata*. The species described by Dall has a strong posterior flexure but the shape of the pallial sinus is quite different from that on the corresponding valve of *M. indentata*. Weaver (1049) compared *M. moliniana* with *M. nasuta* and cited it as occurring in beds of Oligocene age.

Macoma indentata has been reported from beds of Pliocene age in the Los Angeles basin, in San Joaquin Valley, in the Santa Maria district, as well as at Coos Bay, Oregon, and elsewhere.

Simonova (1050) reported *M. indentata* as occurring in late Tertiary beds on Sakhalin Island but we have not seen specimens from there.

Macoma (Rexithaerus) indentata tenuirostris Dall
Plate 41, Figure 15; Plate 50, Figure 7
Plate 52, Figure 2

Macoma (*indentata* Carpenter, var.?) *tenuirostris* Dall, Proc. U. S. Nat. Mus., Vol. 23, No. 1210, p. 324, November 14, 1900. P. 309, as "*Macoma (Rexithaerus) indentata* var. *tenuirostris* Dall."

Macoma identata tenuirostris Dall, Johnson and Snook, Seashore Animals of the Pacific Coast (Macmillan Co.: New York), ed. 1935, p. 451, fig. 443. "Santa Barbara Islands to San Diego (Kelsey)." Recent.

Type specimen. — No. 73469, United States National Museum.

Type locality. — "San Pedro, California." (Dall.)

Range. — Middle Pliocene to Recent. Recent from Santa Barbara, California, to Ensenada, Lower California, Mexico, in 91 to 137 meters (50 to 75 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305A, 331.

Original description. — "This form differs from the typical *indentata* in being more elongated, with a shorter and more pointed posterior end and deeper flexure." (Dall, p. 309.)

"For the rostrate form, pending the acquisition of more and fresh material, I would propose the varietal name of *tenuirostris.* It measures: lon. 55, alt. 33, and diam. 16 mm. The nearest specimen of the typical form measures respectively 44, 31 and 12 mm. The beaks are 25 mm behind the anterior end and in *tenuirostris* 33 mm behind it. The left valve is notably flatter than the other in the type [*M. indentata*], while in the only pair we have of the variety the valves, though flexuous, hardly differ in degree of convexity." (Dall, p. 324.)

Remarks. — *Macoma indentata tenuirostris* is here reported from the San Diego Formation for the first time. A right valve (the posterior end incomplete), is 40 mm long and 28 mm high. Faustman (1051) illustrated a fossil that is probably this subspecies, from the Rio Dell Formation of Pliocene age in Humboldt Co., California. It also has been reported from beds of late Pleistocene age in the Newport Bay (1052) area in southern California.

Some authors (1053) have considered this subspecies to be without taxonomic significance. We have examined six Recent right valves from San Diego in the Henry Hemphill collection of the California Academy of Sciences. The largest one is 55 mm long and 33.5 mm high, the beak is 31 mm from the anterior end. The posterior end is rostrate and pointed. These differ from typical *M. indentata* in the shell characters enumerated by Dall.

Fossil specimens in the present collection, 25 to 30 mm in length appear to be comparatively longer in outline than do adult forms.

Macoma copelandi Wiedey (Trans. San Diego Soc. Nat. Hist., Vol. 5, No. 10, p. 149, pl. 19, fig. 2, March 31, 1928) described from the Temblor Formation in San Luis Obispo Co., is less attenuated posteriorly and more inflated anteriorly in comparison to *M. i. tenuirostris* Dall.

GENUS *FLORIMETIS* OLSSON AND HARBISON

Florimetis Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Mon. 8, p. 129, November 6, 1953. "Type herewith designated: *Tellina intastriata* Say. Recent, Florida." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 410, 1961. Type as designated by Olsson and Harbison.

Type species (by original designation, Olsson and Harbison, 1953): — *Tellina intastriata* Say [Jour. Acad. Nat. Sci. Philadelphia, Vol. 5, Pt. 2, p. 218, February, 1826. "Coast of East Florida." Illustrated by Olsson and Harbison, 1953, p. 129, pl. 15, figs. 1, 1a, 1b. Key West, Florida, Recent. — Afshar, Geol. Soc. Amer., Mem. 119, p. 92, pl. 39, figs. 1-5, 1969 (as *Apolymetis (Florimetis) intastriata.*) Florida.]

Range.—Late Oligocene to Recent. Recent in warm temperate and tropical waters, from the littoral zone to 46 meters (25 fathoms).

Original description. — Shell broadly subovate, inequivalve with a wide, depressed, or wing-like posterior area, which in the right valve is set-off by an angled keel extending from the beak to the posterior extremity. Both valves are strongly convex along the anterior umbonal slope, the right valve being impressed just behind it or across the middle. Interior shows the adductor scars plainly marked in the adult, the anterior scar being narrow, elongated or lucinoid, with the pallial line attached to its hinder end, posterior scar rounded and placed quite low. Pallial sinus deep, reaching nearly to the anterior adductor scar and confluent below with the pallial line by more than half its length. Hinge with small cardinal teeth, the left anterior and the right posterior being bifid, no laterals. Ligament strong, external, the resilium portion forming the larger part of the scar. Exterior white or colorless, the surface sculpture smoothish or of finely crowded growth lines, much heavier on the posterior wings. (Olsson and Harbison.)

Remarks. — The species in the present paper referred to the genus *Florimetis* has been cited in earlier literature under the generic names *Metis* (1054), *Polymetis* (1055), and *Apolymetis* Salisbury (1056).

Olsson and Harbison, and later Keen, pointed out that the west American species referred to *Apolymetis* are quite different from the East Indian species, *Tellina meyeri,* the type species of that genus. The outline of the type species of *Florimetis* is subquadrate, the posterior flexure very well developed, the anterior end is rather inflated and the posterior portion is sculptured with rather coarse concentric lines of growth. This is quite different from the oval outline and fine, regular concentric lines of growth on *Tellina meyeri.*

Olsson and Harbison recognized *Florimetis* as a subgenus of *Hemimetis* Thiele (1057), and Keen placed it as a subgenus of *Psammotreta* Dall (1058). Olsson, 1961, gave *Florimetis* generic status and we follow this practice, at least until there is general agreement concerning the nomenclature of the supraspecific units of the Tellinidae.

Weaver and Kleinpell recently reported a species under the name of "*Apolymetis cf. A. sespeensis* (Loel and Corey)" (1059) from strata believed to be of Oligocene age. That species was originally described under the genus *Macoma* and the illustration by Weaver and Kleinpell bears a general resemblance to some species of *Macoma,* such as *Macoma constricta* Bruguière (1060). The fossil is not referable to *Florimetis s. s.* Weaver and Kleinpell mentioned that *Poromya teglandae* Weaver, 1942, and *Apol-*

ymetis twinensis Durham are synonymous with *Macoma sespeensis* Loel and Corey, 1932.

"Metis" rostellata Clark and *"Metis" vancouverensis* Clark and Arnold were described from strata assigned an Oligocene age.

Florimetis biangulata Carpenter
Plate 53, Figures 14, 17, 19

T[ellina]. alta Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 258, 1837. "Inhabits coast of California, near Sta. Barbara."

Not *Tellina alta* Conrad, Fossil Shells of the Tertiary Formations of North America (reprint by G. D. Harris, 1893), Vol. 1, no. 4, p. 41 (67), October, 1833.

?Scrobicularia biangulata Carpenter, Proc. Zool. Soc. London for 1855, p. 230, February 5, 1856.

Arcopagia medialis Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, p. 314, December, 1856 [1857]. "Monterey Co., Cal." "Middle Tertiary." — Conrad, U. S. Pac. Railroad Expl., Vol. 6, Pt. 2, No. 2, p. 70, pl. 2, fig. 6, 1857.

Arcopagia unda Conrad, U. S. Pac. Railroad Expl., Vol. 7, p. 192, pl. 4, figs. 3, 4, 1857. "Shore of Santa Barbara county, California." Miocene.

Metis alta Conrad, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 160, 1903. "Pliocene at Pacific Beach." — Arnold, U. S. G. S., Prof. Paper 47, p. 28, 1906. "San Diego Formation as developed in the type section at Pacific Beach, north of San Deigo. . .", Pliocene. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 172, 181 1912. "San Diego-Purisima." — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 151, 1919. "San Diego" Pliocene. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 169, pl. 57, fig. 3, 1924. Pliocene to Recent. — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 84, 1929. "San Diego Pliocene."

Apolymetis biangulata Carpenter, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 363, pl. 20, fig. 16 (Barlow Canyon, Pleistocene), 1931. "Pliocene of Pacific Beach, San Diego (Arnold 1903)." — Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 89, pl. 24, fig. 1; pl. 25, fig. 12, 1950. "Miocene (?) to Recent." — Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 72, fig. 38, 1953. "Point Conception, California, to San Quentin, Baja California," Recent. — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 107, pl. 14, fig. 5, 1958. (Carpenter's original description; type specimen illustrated.)

Florimetis biangulata Carpenter, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 64, pl. 30, figs. a, b, 1968. San Diego, Pleistocene. Also "Pliocene at Pacific Beach."

Type specimen. — No. 61.5.20.117, British Museum (Natural History).

Type locality (of *Scrobicularia biangulata*). — "Hab. Sta. Barbara; legit. T. Nuttall, Esq. Museo suo."

Range. — ? Early Miocene (Vaqueros and Temblor). Late Miocene to Recent. Recent, Point Conception, California, to San Quintín Bay, Lower California, Mexico, from littoral zone to 46 meters (25 fathoms); often along the outer coast in coarse sand and gravel or near boulders.

Occurrence in San Diego Fm. — C.A.S. 12, 114. L.A.M. 305. U.C.L.A. 312.

Original description of *?Scrobicularia biangulata.* —? S. t. suborbiculari, subaequilaterali, convexiscula, striis concentricis vix regularibus, postice undata, angulis duobus subobsoletis; ligamento externo tenuissimo, in sulcos alte impresso, semi-interne sito; ligamento intermo fossa trigonali scalena sito, alteri adjacente; dentibus cardinalibus in utraque valve duobus, contiguis, vix radiantibus; cicatricibus muscularibus subovalibus, sinu palii maximo; alba, intus aureo tincta. Long. 1.5, lat. 1.78, alt. .8 poll. (Carpenter.)

Remarks. — A specimen of this species collected by Henry Hemphill in the San Diego Formaton is approximately 71 mm long, 55mm high and the convexity (both valves together), 30.5 mm. Three single valves, the largest one about 60 mm long, were collected near the Mexican boundary by George P. Kanakoff.

This large, suborbicular tellinid attains a length of about 83 mm. It can be readily recognized by the well developed posterior fold, and anterior to this a shallow but pronounced submedian concavity extends from near the umbos to the ventral margin of the right valve. The hinge of each valve has two teeth, the right posterior and the left anterior ones the larger. On a Recent specimen 72.4 mm long the pallial sinus extends forward 52 mm and joins the pallial line 36 mm from the posterior end of the shell.

The longer ligamental area, wider hinge plate, and higher cardinal teeth are features which serve to separate *Florimetis biangulata* from the tropical west American species, *F. cognata* Pilsbry and Vanatta (1061) of which *F. clarki* Durham (1062) is a variety. *Florimetis cognata* often has been recorded in the literature under the name of *"Metis" excavata* Sowerby (1063), a species with a wedge-shaped posterior end and described without information as to the locality from which it came. Study of the hinges of *F. biangulata* and *F. cognata* led Durham to doubt the reported occurrences of the former in beds of Miocene age. It also is quite possible that various records of the occurrence of *F. biangulata* in subtropical west American waters may be questionable. It has been recorded in beds of Pliocene age at various localities in the San Joaquin Valley and in southern California but not in the northern part of the state. However, it does occur in beds of Pleistocene age at Tomales Bay, Loc. 563 (CAS), in central California.

Dall (Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1044, 1900) pointed out that a poorly preserved fossil from Santa Barbara Co. described by Conrad in 1857 as *Arcopagia unda*, is probably identical with the present species.

Khomenko (1064) recorded the occurrence of *"Metis alta"* in the late Tertiary of Kamtschatka but the identity of that form with the present species needs confirmation.

Keen (1065) recently stated that two species (1066) described from the Orient in 1855, *Tellina turgida* Deshayes from "Catbalonga, Philippines," and *Tellina obesa* Deshayes from "China Seas," are probably identical with *Scrobicularia biangulata* Carpenter. She gave reasons for preferring usage of the name *Tellina obesa* rather than *T. turgida* if the Internatl. Comm. on Zool. Nomencl. should rule that the species name proposed by Carpenter should be replaced by one of the earlier names of Deshayes.

FAMILY SEMELIDAE STOLICZKA (1067)

Description.—Shell round or ovate in outline, valves gently convex, the posterior end with an obscure fold; resilium internal, resilifer elongate and nearly parallel to the hinge; hinge with two cardinal teeth, and usually with laterals; pallial sinus long and wide. Eocene to Recent.

Remarks. — The internal resilium serves to separate this family from the Tellinidae in which the resilium is external.

Yonge (1068) discussed the structure and adaptation of members of this family, most of which live on sandy bottoms and have long siphons.

Key to genera of Semelidae

A. Pallial sinus free from the pallial line . . . . . *Semele*

B. Pallial sinus confluent with the pallial line . . . . . *Cumingia*

GENUS *SEMELE* SCHUMACHER

Semele Schumacher, Eassai Nouv. Syst. Vers. Test., p. 165, pl. 18, fig. 2, 1817. Sole species, *Tellina reticulata* Spengler. — Lamy, Jour. de Conchyl., Vol. 61, No. 3, p. 314, 1914. "dont le type est *S. reticulata* Sow. = *S. proficua* Pult." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 375, 1931. "Type (by monotypy), *Tellina reticulata* Spengler = *Tellina proficua* Pulteney; Caribbean; Recent."

Type species (by monotypy and by original designation). — *Tellina reticulata* Spengler [Skrift. Nat. Selsk., Vol. 4, Heft 2, p. 115, 1798.] [= *Tellina proficua* Pulteney, Catalogues of the Birds, Shells, . . .Plants, . . .Doretshire, p. 29, pl. 5, fig. 4 (as *T. reticulata*), 1799. "On the sands at the North shore, Poole, and at Weymouth." [Locality erroneous. This species lives along the coast of southeastern United States and in the West Indies.] Illustrated (hinge) by Lamy, 1914, p. 315, also illustrated by L. Perry, Bull. Amer. Paleo., Vol. 26, No. 95, p. 77, pl. 16, fig. 103, 1940. Southwest Florida in 3 to 6 fathoms. Concerning *T. proficua* see Bowden and Heppell (Jour. Conch. Vol. 26, No. 5, pp. 324, 328, 1969)].

Range. — Eocene to Recent. Recent chiefly in warm temperate and tropical waters. From the littoral zone to about 112 meters (61 fathoms), perhaps deeper.

Description. — Shell oval or suborbicular, slightly inequivalve, usually more or less rostrate posteriorly. Umbones subcentral, low, proximate, prosogyrate. Ligament short, external; resilium strong, internal. Hinge armature of 2 cardinals and 2 laterals in each valve, the laterals of the right valve usually stronger. Adductor impressions large, semielliptical. Pallial sinus profound. (Gardner, J., U. S. G. S., Prof. Paper 199, p. 100, 1948.)

Remarks. — Five species of *Semele* have been reported from the Tertiary of California. Another one is here recorded for the first time from the San Diego Formation. Over thirty species now live in tropical and subtropical waters of the western Americas.

Lamy (1069) published a summary of the species of this genus represented in the collections of the Natural History Museum in Paris. Dall (1070) published notes on the west American species of *Semele* and more recently Hertlein and Strong (1071) discussed and illustrated a number of species from this region, as have Keen (1072), and Olsson (1073).

Key to Species of *Semele*

A. Concentric rugae rounded, sometimes nearly obsolete; a small, narrow, depressed lunular area present . . . . . *rubropicta*

B. Concentric rugae flat-topped, regular; depressed lunular area slight or lacking . . . . . *ashleyi*

Semele ashleyi n. sp.
Plate 48, Figures 3, 4, 6, 9, 10

Semele cf. *S. rubropicta* Dall, Woodring, in Woodring and Bramlette, U. S. G. S., Prof. Paper 222, p. 88, pl. 14, fig. 12, 1950. "Foxen mudstone at the Waldorf asphalt mine, in the Cebada member of the Careaga sandstone at Fugler Point and locality 177, and may be present in diatomaceous strata of the Sisquoc formation." Santa Maria district, southern California.

Type specimens. — Holotype and paratypes in Los Angeles County Museum, Department of Invertebrate Paleontology.

Type locality. — Loc. 305C (LAM), exposure at hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U. S. G. S. topog. map, San Ysidro quad., rev. 1953).

Range. — Middle Pliocene.

Occurrence in San Diego Fm. — L.A.M. 305, 305C, 318.

Description. — Shell elongately ovate, the posterior end shorter, the posterior ventral margin faintly truncated, the general outline and shell characters similar to those of *Semele rubropicta*. Sculpture consists of rather coarse, slightly flattened, concentric ridges which increase, in width with growth of the shell, these are separated by incised grooves which are about one third to one fourth the width of the ridges; both ridges and grooves are crossed by fine, shallow, irregularly spaced radial lines, most readily observable on slightly eroded specimens; hinge of right valve with an anterior cardinal, a central cardinal followed by ligamental area, an anterior and a posterior lateral are present, left valve with a thick anterior cardinal, followed by a thin central cardinal and a resilial pit, an anterior and a posterior lateral are present; pallial sinus broad, slightly ascending, the end broadly rounded and faintly ellipsoid at the distal portion. Dimensions of holotype; length 40.5 mm, height 37 mm convexity (both valves together) 23.6 mm, pallial sinus extends anteriorly 28.5 mm from the posterior end of the valve.

Remarks. — The holotype, single valves, and several fragments of this new species, in the collections of the Los Angeles County Museum from near the Mexican boundary, were available for study.

This species appears to be identical with the one

illustrated by Woodring (1050) as "*Semele* cf. *S. rubropicta* Dall" from strata of Pliocene age in the Santa Maria district in Santa Barbara Co., California.

The concentric ridges of *Semele ashleyi* n. sp. are coarser and are separated by wider and more deeply incised grooves than those on *S. rubropicta*. Also the lunular area beneath the beaks of *S. ashleyi* is only slightly depressed whereas on *S. rubropicta* there is a small but well developed, narrow, depressed lunular area (see plate 48, figure 7).

One lot of Recent specimens, 3 paired valves, the largest 30.5 mm long, and several small single valves of a *Semele* in the collections of the California Academy of Sciences collected by Henry Hemphill from roots of kelp in deep water off San Diego, California, closely resemble the fossil form here described from the San Diego Formation. The chief differences noticed in comparison of this lot of Recent specimens with specimens of the new species of comparative size, are that the ribbing on the umbos of the Recent shells becomes coarser at an earlier stage of growth and the depressed lunular area is comparatively larger than it is on *S. rubropicta*.

A small right valve from Loc. 305 (LAM) illustrated on Plate 48, Figures 4 and 8, is probably a juvenile form of *S. ashleyi* n. sp.

This new species is named for Dr. George H. Ashley, author of an important paper (1895) dealing with the Pliocene of central California.

Semele rubropicta Dall
Plate 48, Figures 1, 2, 7, 11

Semele rubropicta Dall, Amer. Jour. Conch., Vol. 7, Pt. 2, p. 144, pl. 14, fig. 10, November 2, 1971. "Habitat. Beach as Soquel, Monterey Bay, two or three valves, Dall; San Pedro, Cooper; Neah Bay, one worn valve, Swan." — Arnold, U. S. G. S., Bull. 396, pp. 31, 156, pl. 25, fig. 3, 1909. "Upper Etchegoin formation." — I. S. Oldroyd, Publ. Puget Sound Biol. Sta. Vol. 4, p. 56, pl. 22, fig. 10, 1924. [Copy of original figure.] Off San Juan and Lopez Islands, Washington, also other locs. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 180, pl. 43, fig. 10, 1924. [Copy of original figure.] "Forrester Island, Alaska, to Tia Juana, Lower California." — Dall, Proc. U. S. Nat. Mus., Vol. 66, Art. 17, p. 26, pl. 18, figs. 1, 2, 1925. "Beach at Soquel, Monterey Bay, Calif."— Johnson and Snook, Seashore Anim. Pac Coast (Macmillan Co.: New York), ed. 1935, p. 453, fig. 448. Alaska to Lower California. — Stewart, in Woodring, Stewart and Richards, U. S. G. S., Prof. Paper 195, p. 33, list opp. p. 38 and list opp. p. 78, pl. 11, fig. 18, 1940 [1941] (as *Semele* cf. *S. rubropicta*). — Abbott, Amer. Seashells (D. Van Nostrand Co.: New York, London, Toronto,) p. 435, pl. 29, fig. W., 1954. "Alaska to Mexico."

Type specimen. — No. 101960, United States National Museum.

Type locality. — "Beach at Soquel, Monterey Bay, Calif." (Dall, 1925.)

Range. — Early Pliocene (Jacalitos) to Recent. Recent from Forrester Island, Alaska, to Tijuana, Lower California, Mexico, in 37 to 91 meters (20 to 50 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305, 305C, 318.

Original description. — Shell usually pure white and brilliantly polished within, but occasionally with a faint yellowish or pinkish flush when very deeply colored externally. Inner margin, except on the hinge-line, always pure white. Outside, covered with a thin yellowish green or olive, epidermis usually wanting, color yellowish white, with rose-pink and pure white rays, color stronger on the lines of growth. Sculpture consisting of incised lines radiating from the umbones where they become obsolete; crossed by rounded, smooth, concentric ridges rather sharply defined by concentric grooves. These ridges are usually regular but sometimes bifurcating. In perfect specimens the radiating lines and grooves are so sharp that their intersections appear as if punctured. Ligament pit deep and excavated, cardinal and lateral teeth moderate. Anterior end much produced, rounded, margin rounded below, posterior end very short, almost truncated; shell rather inflated. Lunule deeply impressed, narrow, lanceolate, short. General form subquadrate. Umbones inconspicuous, usually tinged with yellow. Hinge-line below the lunule with a purple spot. Interior marked with extremely faint radiating lines. Posterior portion of the inferior margin produced. Shell thick and solid. Alt. 1.35 in. Lon. 1.55 in. Diam. .7 in. Lunule .24 in. (Dall.)

Remarks. — A well preserved specimen from Loc. 305C, (L.A.M.), is 42.8 mm long, 36 mm high, convexity (both valves together) 22 mm and a right valve from the same locality, the ventral portion incomplete, is 47.5 mm long. One fairly well preserved right valve, 45.6 mm long and 39 mm high, is present in the collection from Loc. 318 (LAM). A number of fragments and small valves also are present at Loc. 305 (LAM) near the Mexican boundary. The sculpture on these fossils varies as it does on Recent specimens.

The largest Recent specimen in the collections of the California Academy of Sciences, from Puget Sound, is 50.5 mm long, 41.8 mm high, convexity (both valves together), 24.8 mm, the broadly rounded pallial sinus extends anteriorly 31.5 mm from the posterior end of the valves.

Sculpture in this species varies from specimen to specimen and sometimes varies on the two valves of the same specimen. The concentric sculpture may be very fine or fairly coarse and fairly regular to irregularly spaced. Some Recent shells bear deep concentric grooves at intervals of from 3 mm to 10 mm on some specimens in the collections of the California Academy of Sciences, the umbonal area is nearly smooth. The shells of this species in the northern portion of their range are relatively smooth whereas those in more southern waters tend to develop concentric rugae.

Semele fausta Nomland (Univ. Calif. Publ. Bull. Dept. Geol., Vol. 10, No. 4, p. 233, pl. 9, figs. 3, 3a, 3b, April 19, 1917) described from Etchegoin beds of Pliocene age in middle California, differs from *S. rubropicta* in the more posteriorly situated beaks and in other details.

GENUS *CUMINGIA* SOWERBY

Cumingia Sowerby, Proc. Zool. Soc. London for 1833, p.

34, May 17, 1833. Four species cited including *Cumingia lamellosa* Sowerby. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 998, 1900. "Type *C. mutica* Sby." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 370, 1961. Type as designated by Gray, 1847.

Type species (by subsequent designation, Gray, Proc. Zool. Soc. London for 1847, p. 187). — "*C. lamellosa*" [*Cumingia lamellosa* Sowerby, 1833, p. 34. "Hab. prope littora Oceani Pacifici." "Found at Payta in hard clay at low water; and at Panama in deep water." — Sowerby, Reeve's Conch. Icon., Vol. 19, *Cumingia*, species 5, pl. 1, fig. 5, 1873. "Hab. Chili." — Olsson, 1961, p. 371, pl. 66, figs. 10, 10a; pl. 67, figs. 3, 3a, 1961. Gulf of California to northern Peru].

Range. — Miocene to Recent. Recent in the western Americas from Crescent City, California, to Chile, nestling in holes bored by mollusks or in crevices in rocks, piling, gravel, etc., from the intertidal zone to 46 meters (25 fathoms). Also Japan and western Atlantic, from the littoral zone to 91 meters (50 fathoms).

Description. — Shell often distorted but normally equivalve, inequilateral, anteriorly rounded, posteriorly subtruncated and slightly gaping; lunule small and escutcheon larger in left valve; sculpture principally concentric, formed by elevated ridges, their interspaces minutely striated or sagrinated; ligament partially external and internal, the external ligament small and overlies a large posteriorly directed chondrophore or resilifer developed equally in both valves; anterior side of resilifer bordered by a small cardinal tooth and socket; right valve with two strong lateral teeth bordered above by sockets into which fit the thickened margins of the other valve; pallial sinus large, confluent below with the pallial line. (Adapted from H. and A. Adams, Gen. Rec. Moll., Vol. 2. p. 412, 1858, and Olsson and Harbison, Acad. Nat. Sci., Philadelphia, Monogr. No. 8, p. 135, 1953.)

Remarks.—The genus *Cumingia* was recorded doubtfully from the San Diego Formation by Dall and the present record is based upon fragments retaining portions of the hinge. This genus has been reported from Pliocene to Recent in western North America but in eastern North America it is known to occur in beds of Miocene age. A species was described as "*Cumingia?antiquata*"(1074) by Philippi from beds of Tertiary age in Chile but an inspection of the illustration convinces us that the generic assignment is doubtful. Von Ihering (1075) stated that *Cumingia* does not occur in beds of Tertiary age in Patagonia

Cumingia? keittensis Harris was described from strata of Eocene age in Alabama but the generic assignment remains open to question.

The genus *Cumingia* is represented in strata of Pliocene and Pleistocene age in California by but one species which also lives in adjacent waters. One species, *C. densilineata* Dall, was described from beds of Pleistocene age at San Quintín, Lower California. Several Recent species have been described from more southern waters but it is apparent that there are too many names for the species represented. However, at least three species live in the region between California and Chile.

Dall (1900, p. 999) pointed out that on both the Pacific and Atlantic coasts of the United States, the species in the northern part of their ranges are larger, the sculpture is more regular and less sparse, whereas in the southern part of their ranges, the shells diminish in average size and concentric lamellae become relatively more prominent. The shell of *Cumingia* is variable in shape and sculpture as a result of the animal's habit of nestling in holes and crevices.

The soft parts of *Cumingia* were described by Deshayes (1076), and Grave (1077) discussed the natural history of *C. tellinoides.*

The Recent species of *Cumingia* in the Natural History Museum in Paris were discussed by Lamy (1078).

Stoliczka, 1871, placed *Cumingia* in a subfamily cuminginae.

Cumingia cf. C. californica Conrad

The following references refer to typical *Cumingia californica. C.[umingia] californica* Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 234, pl. 17, fig. 12, 1837. — Dall, Proc. U. S. Nat. Mus., Vol. 1, p. 11, 1878. "Later Tertiary" of San Diego. Also Recent. — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 1001, 1900. "Pliocene of San Diego?; Hemphill." — Arnold, Smithsonian Misc. Coll. (Quart. Issue), Vol. 50, Pt. 4, p. 445, pl. 56, fig. 5, 1907. "Fugler Point asphalt mine, near Gary," California, Pliocene. Also Recent. — Arnold, U. S. G. S., Bull. 322, pp. 58, 148, pl. 23, fig. 5, 1907 (1908). Some records as in preceding reference. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 171, 181, 1912. "San Diego-Purisima," Pliocene. — Lamy, Jour. de Conchyl., Vol. 61, No. 3, 1914. "San Diego," Recent. — Abbott, American Seashells. (Van Nostrand Co.; New York), p. 436, pl. 31, fig. V, 1954. "Crescent City, California, to Chile."

Type specimen. — Location of the type specimen unknown to the present authors.

Type locality. — "*Inhabits* with the above; rare." [The above is *Sphenia californica* from "*Inhabits* salt marshes, near Sta. Barbara; rare."]

Range.—Pliocene (Jacalitos) to Recent. Recent from Crescent City to San Martin Island, Lower California, Mexico, from the intertidal zone to 46 meters (25 fathoms), in holes bored by mollusks and in crevices in rocks, piling, and in gravel.

Occurrence in San Diego Fm. — L.A.M. 305.

Original description. — Shell triangular, convex, thick, with numerous irregular lamellar concentric striae; posterior side compressed, cuneiform; beaks central, rather prominent; lateral teeth prominent. Length, one inch and one-fourth. (Conrad.)

Remarks. — The present record of *Cumingia californica* in the San Diego Formation is based upon three fragments, of which one left valve retains a part of the hinge with most of the chondrophere and a small tooth anterior to it. An occurrence of *Cumingia californica* in strata of Pliocene age at San Diego would not be out of place because it has been reported from beds of Pliocene age in San Joaquin Valley and in the Cebada Member of the Careaga Formation in the Santa Maria district along with other species which likewise occur in the San Diego beds.

Strong (1079) pointed out that *Cumingia californica*

at times has been confused with more southern species, especially *C. lamellosa* Sowerby (1080). The latter species is only about a fourth the size of *C. californica* and is more triangular in outline. *Cumingia lamellosa* Sowerby is a different species from the one described as *Thyella lamellosa* H. Adams (1081) (=*C. elegans* Sowerby) from the East Indian Archipelago and Australia, a species placed at times by some authors in the genus *Cumingia.*

A large specimen of *Cumingia californica* in the Academy's collection, taken at San Diego by Henry Hemphill, is 30.1 mm long, 22.8 mm high, the convexity (both valves together) 11.8 mm, the pallial sinus extends forward 20 mm from the posterior end of the valve and joins the pallial line after a short bend posteriorly. The hinge of the right valve has a lateral tooth on each side and the left valve has a small cardinal tooth in front of the ligamental pit. A weak lateral or extension of the margin on each side fits into sockets in the opposite valve.

The shell of this species is often distorted because of the animal's habit of nestling in crevices in rocks and other objects.

FAMILY DONACIDAE FLEMING

The shell is generally transversely trigonal to cuneiform, equivalve, solid in texture, with entire or crenulated and usually closed margins. The surface is smooth or with fine radial lineation or riblets. The ligament is external, short, usually opisthodetic, and attached to and along a nymphal plate. Pallial line distinct, placed a short space above the margin, its sinus short or of medium length, generally directed horizontally, its end well rounded. The adductor scars are subequal in size and often deeply impressed. Substance of the shell is usually coarse; porcellaneous, white externally or grading into violet or purple, the same coloration in the interior. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 336, 1961.) Late Cretaceous to Recent.

Remarks. — An account of the structure and adaptation of the shells of this family of mollusks was published by Yonge (1082) and Chavan (1083) discussed the systematic position of members of this family. Many of the Recent tropical west American species were discussed by Hertlein and Strong (1084), by Keen (1085), and by Olsson (1086).

GENUS *DONAX* LINNAEUS

Donax Linnaeus, Syst. Nat., ed. 10, p. 682, 1758. *Donax rugosa* Linnaeus included in original list of species. — Römer, Syst. Conchyl. - Cab. von Martini und Chemnitz, Bd. 10, Abt. 3, p. 4, 1871.—Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 378, 1931. Type (as designated by Herrmannsen): "*Donax rugosus*" Linnaeus.—Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 77, 1952. Type (as designated by Schumacher): *Donax rugosus* Linnaeus.

Type species (designated by Schumacher, Essai Nouv. Syst. Vers Test., p. 144, 1817.) — "*Donax rugosa* Lin." Ref. to "Pl. XIII. fig. 4. Chemn. 6, pag. 254. Tab. 25. fig. 250." This species also was designated as the type species of *Donax* (of Lamarck) by Schmidt, Versuch Conchyl. - Samml., pp. 55, 176, 1818; also designated as type by Herrmannsen, Indic. Gen. Malac., Vol. 1, p. 404, 1847, and by Gray, Proc. Zool. Soc. London for 1847, p. 187. [*Donax rugosa* Linnaeus, Syst. Nat., ed. 10, p.682, 1758. "Habitat in O. meridionali." Ref. to Gualtieri, Test., pl. 89, fig. D. Illustrated by Reeve, Conch. Icon., Vol. 8, *Donax*, sp. 9, pl. 2, figs. 9a, 9b, 9c, 1854. "Hab. Gold Coast, West Africa."—Nicklés, Moll. Test. Mar. Cote Occid. d'Afrique. Man. Ouest - Africains, Vol. 2, p. 211, fig. 405 (p. 212), 1950. See also Dodge, 1952, p. 80.]

Range. — Eocene to Recent. Recent, world wide in warm temperate and tropical waters, from between tides to about 82 meters (45 fathoms), on sand.

Description. — Shell moderately small, elongate-trigonal to subcylindrical in outline, closed; beaks prosogyrous, posterior to subcentral; anterior end produced and rounded, posterior end short, sometimes truncated; sculpture consists of fine radial riblets, sometimes punctate; ligament external; hinge usually with two cardinals in each valve, one commonly bifid, laterals variable; pallial sinus deep, horizontal, partly confluent with pallial line ventrally; margins usually crenulated.

Remarks.—*Donax* apparently is not known to occur earlier than Eocene time. *Notodonax* Ferruglio (1087) was described from beds of late Cretaceous age in Argentina and *Protodonax* Vokes (1088) was described from strata of late Cretaceous age in Wyoming.

At the present time, about one hundred species of *Donax* live in very shallow, warm temperate and tropical marine waters. The northern range of this genus along the coast of California is about 35° 10′ 00″ N.

[*Donax californicus* Conrad]

D[onax]. californica Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 254, pl. 19, fig. 21, 1837.—Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, p. 968, December, 1900. "Pliocene of San Diego, California, Well."

Donax flexuosus Gould, Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 238, 1888. "Pl. — San Diego Well."

Not *Donax flexuosus* Gould, 1853 = *D. striata* Linnaeus, 1767. See Dall, 1900, p. 968.

Type specimen. — Twelve syntypes, No. 61.5.20.91, British Museum (Natural History) (A. M. Keen, Veliger, Vol. 8, No. 3, p. 170, 1966.)

Type locality. — "Inhabits the coast of California in sand, near Sta. Barbara."

Range. — Pleistocene to Recent. Recent, Goleta, California, to Magdalena Bay, Lower California, Mexico. "Found in sand or sandy mud of bays, lagoons and estuaries and other localities not exposed to the pounding surf." (Fitch).

Occurrence in San Diego Fm. — San Diego well (Cooper; Dall).

Remarks. — This species was recorded by both Cooper and Dall as occurring among the fossils from the San

Diego well. We have not seen specimens of it in any collections from the San Diego Formation. It occurs commonly in Pleistocene beds in southern California and northern Lower California. It has not been recorded from strata of Pliocene age, so far as we know, by any modern author.

The shell of *Donax californicus* differs from that of *D. gracilis* Hanley (1089), an inhabitant of tropical and subtropical west American waters, in that it is less elongated and the posterior dorsal margin slopes more steeply ventrally.

Recent specimens of *Donax californicus* Conrad were illustrated by Hertlein and Strong (1949, pl. 1, figs. 2, 5) and by Fitch (1090).

SUBGENUS *SERRULA* CHEMNITZ

Serrula Chemnitz, Mörch, Cat. Conchyl. Yoldi, Pt. 2, p. 18, 1853. Several species cited including *Donax trunculus* Linnaeus.—Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 379, 1931. "Type (by subsequent designation, Dall, 1900), *D. trunculus* Linnaeus."

Type species (designated by von Martens, Zool. Rec., Vol. 7, Moll., p. 172, 1870). — "Type *trunculus*, L." [Illustrated by Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 9 (Pelecypoda, Fasc. 22), p. 454, pl. 68, figs. 1, 2, 3, 4, 1893. European seas. For a discussion of this species see Dodge, Bull. Amer. Mus. Nat. Hist. Vol. 100, Art. 1, pp. 80-81, 1952.]

Range. — Pliocene to Recent.

Description. — Shell oval-triangular, cuneiform, gibbous in front; margins denticulated within; hinge with oblong cartilage fissure. (Tryon, 1884.)

Remarks. — The subgeneric assignment of some of the west American Cenozoic species of *Donax* is not entirely satisfactory. However, the following species from the San Diego Formation appears to be better placed in *Serrula* than in any other supraspecific group.

Donax (Serrula) gouldii Dall

Plate 48, Figures 16, 19; Plate 57, Figure 8

Donax obesus Gould, Proc. Boston Soc. Nat. Hist., Vol. 4, p. 90, November, 1851. — Gould, Boston Jour. Nat. Hist., Vol. 6, p. 394, pl. 15, fig. 9, 1853. "Inhabits San Diego."

Donax obesus Philippi, Zeitschr. f. Malakozool., Jahrg. 8, No. 5, p. 75, 1851. "Patria: California ex auct. mercatoris, a quo emi."

Not *Donax obesus* d'Orbigny, Voy. Amér. Mérid., Vol. 5, Moll., p. 541, pl. 81, figs. 28, 30, 1846. "Elle a été pêchée à Payta (Pérou) par M. Fontaine."

Donax gouldii Dall, U. S. Nat. Mus., Bull. 112, p. 49, February 24, 1921. "Santa Barbara, California, to Acapulco." Recent. [New name for *Donax obesus* Gould 1851, not *Donax obesus* d'Orbigny, 1846.] — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 183, pl. 49, figs. 8, 9, 1924. "Range. Santa Barbara, California, to Acapulco, Mexico." (On expl. to pl. 49, as *Donax gouldi.*) — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 380, pl. 13, fig. 12, 1931. Pleistocene to Recent.

Donax gouldi Dall, Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 84, fig. 50, 1953. "Range: Pismo Beach, California, to Cape San Lucas, Baja, California."

Type specimen. — Location of type specimen unknown to the present authors.

Type locality. — "San Diego" [California.]

Range. — Middle Pliocene to Recent. Recent from San Luis Obispo, California, to Todos Santos Bay, Lower California, in intertidal zone, on sandy beaches.

Occurrence in San Diego Fm. — L.A.M. 319. U.C.L.A. 294, 311.

Original description (of *Donax obesus* Gould). — T. parva, solida, ovatocuneata, ventricosa, nitida, radiatim leviter striata, coloribus albidis et fulvidis omnino vel radiatiim picta et plerumque zonis violaceis ornata; angulo postero-dorsali rectangulari; facie posteriori cordiformi, subtriangulari; latere antico angustato, citò rotundato; margine ventrali denticulato, posticè coarctato: intus alba, vel flavescens, violaceo nuberculata, ad marginem dorsalem fuscata. Long. 9/10, alt. 6/10; lat. 4/10 poll. (Gould.)

Remarks. — Ten single valves of *Donax gouldii* are present in the collections of the University of California at Los Angeles from near the Mexican boundary. The largest, a left valve, is 19.4 mm in length. Three valves in fairly good state of preservation, the largest one about 20 mm long, and three fragments are present in the collection of the Los Angeles Museum from Loc. 319 (LAM) near the Mexican boundary. The present specimens are comparable to Recent valves of similar size. A large Recent specimen collected by Henry Hemphill at San Diego is 24.6 mm long, 15.3 mm high, convexity (both valves together) 11 mm.

This species is represented in the collections from the San Diego Formation by a comparatively small number of valves. Fitch, 1953, mentioned that at times, billions of living individuals of this species form a solid pavement several layers deep in the sandy beaches in southern California.

Coe (1091) discussed the ecology of *Donax gouldii* and more recently Pohlo (Veliger, Vol. 9, No. 3, pp. 330-337, figs. 1-5, 1967) discussed aspects of the biology of this species.

FAMILY GARIDAE STOLICZKA

The shell is telliniform, donaciform, or soleniform, usually equivalve and if unequal, the right valve is the larger and more convex, usually with a gap at the posterior end. The surface is often highly colored in which shades of red, pink, and purple predominate, spread uniformly or in a streaked, maculated, or rayed pattern; The hinge has one or two, bifid or grooved cardinal teeth; there are no laterals. The ligament is external, large, lies entirely posterior of the beaks and is attached to a large, nymphal plate which rises prominently above the hinge margin. The adductor scars are distinct, placed rather high dorsally and connected by a pallial line bearing a deep sinus. The periostracum is usually coarse and dark in color in some groups, thin and inconspicuous in

others. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 347, 1961, for Family Sanguinolariidae.) Cretaceous to Recent.

Remarks. — The shells of this family resemble those of the Tellinidae but the posterior end is usually less twisted and the valves more gaping, the hinge plate is broader as are the nymphs back of the beaks and the valves are covered with a thicker periostracum.

The species in this family are more numerous in warm waters; about ten or twelve species distributed in five genera have been reported occurring in tropical and subtropical west American waters.

Dall (1093) published a synopsis of the Cenozoic "Psammobiidae" of North America.

Key to Genera of Garidae

A. Sculpture of posterior area differentiated from that on remainder of shell . . . . . *Gari s. s.* (1904)

B. Sculpture on posterior area not differentiated from that on remainder of shell . . . . . *Gobraeus*

GENUS *GOBRAEUS* LEACH

Gobraeus Leach, manuscript name in Brown, Recent Conch. Great Britain and Ireland, edit. 2, p. 102, 1844 (as "*Gobraeus vespertinus*, Leach, MSS." in the synonymy of *Psammobia vespertina*, p. 102, pl. 40, fig 3). —Leach, Synop. Moll. Gt. Britain, p. 265, 1852. Species cited: "*Gobraeus variabilis*" in the synonymy of which are, *Tellina depressa* [refs. to Pennant and Dillwyn], *Tellina variabilis* [refs. to Pulteney and to Donovan]. *Solen vespertinus* [refs. to Bruguière, Wood, and others]. From various localities around Great Britain. — K. V. W. Palmer, Geol. Soc. Amer. Mem. 76, p. 111, 1958. "Type species by monotypy *G. variabilis* Leach=*Solen vespertinus* Gmelin, 1791." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 356, 1961. Type species same as cited by Palmer.

Type species (by monotypy; and by subsequent designation by Dall, Proc. Acad. Nat. Sci. Philadelphia, Vol. 50, p. 57, 1898). — "Type *Psammobia vespertina* Lam. European Seas." [=*Solen vespertinus* Gmelin, Linn. Syst. Nat., ed. 13, Vol. 1, Pars VI, p. 3228, 1791. "Habitat in mari mediterraneo& Atlantico." Illustrated by Wood, Gen. Conch., p. 135, pl. 33, figs. 2, 3, 1835. Mediterranean, Atlantic, and various localities around Great Britain. Also, Reeve, Conch. Icon., Vol. 10, *Psammobia*, species 17, pl. 10, fig. 17, 1865. "Hab. Mediterranean." See also Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Tom. 2, Fasc. 10 (Pelecypoda, Fasc. 23), p. 485, pl. 71, figs. 1-7, 1895 (as *Psammobia depressa* Pennant, fig. 1 (typical), fig. 2 (var. *livida* Jeffreys), figs. 3, 4 (var. *normalis* Bucquoy, Dautzenberg, and Dollfus), figs. 5, 6, 7 (var. *caerulescens* Réquien).]

Range. — Eocene to Recent. Recent from the intertidal zone to 73 meters (40 fathoms), in sand.

Description. — Shell inflated, more or less truncate behind; concentrically striate or nearly smooth, often with fine radial striae, especially evident on the posterior dorsal region; teeth variable, not more than three in the right valve and two in the left valve; sinus rounded in front, rarely shorter than the vertical of the beaks, and often more or less detached from the pallial line. (Dall.)

Remarks. — The shell of *Gobraeus* differs from that of *Gari* in that the posterior dorsal area lacks any differentiation of sculpture from the remainder of the shell other than a coarsening of the concentric threads. The surface of the shells of this genus are often rayed with lilac and purple tints. The valves gape posteriorly.

In recent years, west American species, such as the one referred to the genus *Gobraeus* in the present paper, have been assigned to the genus *Gari* Schumacher (1095). There have been differences of opinion concerning the identification of the type species of *Gari* as revealed in discussions by Stewart (1096), Dodge (1097), Cox (1098), and others.

Schumacher referred to figures 92 and 93 shown on plate 10 by Chemnitz (Neue Syst. Conchyl. — Cab., 1782) and more recently Lemche and Parker (1199) published an illustration of the specimen shown in Chemnitz's figure 93 which was said to have come from Nicobar.

Recently, the Internatl. Comm. on Zool. Nomencl. designated *Gari vulgaris* Schumacher, 1817, as type species of *Gari*, as defined by a lectotype selected by Lemche. This species appears to be identical with *Solen amethystus* Wood, 1815 (1101).

The concentric threads on the type species are offset along a groove or line on the posterior area. This interpretation of the type species of *Gari* results in the relegation of all west American species of this group to the genus *Gobraeus*.

Psammobia Lamarck (1102) has been placed in the synonymy of *Gari* by some authors. Keen recently assigned it subgeneric rank under *Gari*.

Mesozoic (1103) species have been referred to "*Psammobia*". However, according to Gardner (1104) that genus is not known with certainty to occur in the Cretaceous but it was well established by mid-Eocene time. Finlay and Marwick (1105) mentioned that *Gari* first appeared in New Zealand in the Bortonian, late Eocene.

Davies (1106) pointed out that on many species of "*Gari*" of Eocene age, the pallial sinus is rather short and free from the pallial line whereas on typical species the pallial sinus is longer and is confluent with the pallial line.

The genus *Gobraeus* is represented by but one species in the fauna of the San Diego Formation. At the present time three species occur in the waters off California and five species have been recorded occurring in tropical and subtropical west American waters. The west American species of *Gobraeus* usually burrow in sand or sandy mud to a depth of several centimeters. Yonge (1107) discussed the structure and adaptation of British species referred to "*Gari*" and mentioned that they are especially adapted to inhabit substrata of coarse sand or shell and gravel.

Gobraeus endentulus Gabb
Plate 48, Figures 13, 15

?S[iliquaria]. edentula Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 53, pl. 15, fig. 11, 1869.

Psammobia edentula Gabb, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 174, 182, 1912. "San Diego-Purisima." Lower Pliocene. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 185, pl. 57, fig. 1, 1924. Pliocene to Recent.

Psammobia (Gobraeus) edentula Gabb, Dall, Proc. U. S. Nat. Mus., Vol. 66, Art. 17, p. 23, pl. 19, fig. 1, 1925. "San Pedro, Calif.: Recent specimen."

Gari edentula Gabb, Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 281, pl. 13, fig. 3, August 9, 1930. "Horizon, Pliocene; locality, San Fernando." [Lectotype discussed and illustrated.] — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 382, pl. 21, fig. 5 (San Pedro, California, Recent), 1931. Late Miocene to Recent. — Fitch, Calif. State Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 80, fig. 46, 1953. Santa Barbara, California, to San Diego, California, Recent.

Gari (Psammocola) edentula Gabb, Korobkov, Spravochnik I Metodicheskoe Rukovodstvo po tretichnym Molluskam Plastinchatozhabernye [Lamellibranchiata]. Gostoptehizdat [Publishing house], Leningrad, pl. 16, fig. 2 [copy of figure from Grant and Gale], 1954.

Type specimen. — Lectotype No. 15035, Academy of Natural Sciences of Philadelphia.

Type locality. — "From the Pliocene of San Fernando," California.

Range. — Middle Miocene (Temblor, Loel and Corey), to Recent. Recent from Santa Barbara to San Diego, California, in 6 to 24 meters (3 to 13 fathoms), in the more quiet sheltered waters along the outer coast where this species is believed to burrow to a depth of five or six inches (Fitch).

Occurrence in San Diego Fm. — C.A.S. 1129. L.A.M. 178A, 305, 305A, 319. S.D. 2, 4, 331, 365. U.C.L.A. 294, 312, 2359.

Original description. — Shell moderately large, thin, flattened, elongated sub-elliptical, nearly equilateral; beaks minute, a little posterior to the middle, projecting almost insensibly beyond the cardinal line; cardinal margin sloping slightly and perfectly straight towards the two ends; anterior end convexly and very obliquely subtruncate above, produced and rounded below; posterior end broadly and regularly rounded, a little less prominent below than above the middle; basal margin nearly straight. Surface nearly smooth in the middle, marked by pretty distinct lines of growth towards the ends, especially above. Length from beak to base, 1.3 inch; width, 2.6 inch; beak to anterior end, 1.45 inch. (Gabb.)

Remarks. — Several specimens, fairly well preserved, in the collections from the San Diego Formation, are similar to Recent specimens of *Gobraeus edentula.* The largest specimen, from Loc. 4 (SD) south slope of Mount Soledad is 87 mm long, 42.8 mm high, the convexity (both valves together), 17.3 mm. Recent specimens attain a length of about 125 mm. Many fragments from the San Diego Formation in the collections of the Los Angeles County Museum are referable to this species.

The hinge has two cardinal teeth in each valve, those of the left weaker, especially the posterior one which may be reduced to a lamina. Both teeth slope gently posteriorly, the posterior one the more so. There is variation in the size of the teeth in a series of specimens. In some the left anterior tooth is about half its usual height and is flattened on the distal surface.

The pallial sinus extends forward more than one half the length of the shell. On a Recent specimen 125 mm long the pallial sinus extends forward 70 mm and joins the pallial line at about 63 mm from the posterior end of the shell.

The more elongate and more compressed valves sculptured with fine even concentric threads are features which readily serve to separate the present species from *Gobraeus californicus* Conrad, a well known species which has been reported to range from San Diego, California, to Japan.

A fossil cited as "*Psammobia*, aff. *edentula* (Gabb)", was reported by Clark (1108) from the San Ramon Formation which he considered to be of Oligocene age. The preservation of the fossil is so imperfect that identification of the species is uncertain.

The nomenclature of the present species may be involved with that of the earlier *Tellina fucata* Hinds (1109) which was described from Magdelena Bay, Lower California.

FAMILY SOLECURTIDAE D'ORBIGNY

Shell inequivalve, elongated, gaping at both ends. Ligament external. Hinge with or without diverging teeth. (Translation of d'Orbigny, Voy. dans Amér. Mérid., Vol. 5, Moll., p. 522, 1846). Late Cretaceous to Recent, in temperate and tropical seas.

Remarks. — This family is separated from the Solenidae chiefly on the basis of anatomical characters. These characters, were given by d'Orbigny as follows: "Animal muni d'un manteau fermé plus ou moins, ayant une ouverture buccale par où sort un pied volumineux comprimé. A la région anale se trouvent deux tubes distincts et séparés, plusieurs muscles à chaque valve."

Ghosh (1110) gave a detailed description of the soft parts of some members of this family.

GENUS *TAGELUS* GRAY

Siliquaria Schumacher, Essai Nouv. Syst. Vers Test., p. 129, 1817. Species cited, *Siliquaria notata* Schumacher, pl. 7, figs. 2, 3, in synonymy of which are *Solen gibbus* Spengler, *Solen guineensis* Chemnitz, *Solen Tagal*, Adanson.

Not *Siliquaria* Bruguière, Tabl. Encyclop. Méthod. (Vers), Vol. 1, p. XV, 1789. [No species cited.] See also Deshayes, Encyclop. Méthod., Vol. 3, p. 950, 1832.

Tagelus Gray, Proc. Zool. Soc. London for 1847, p. 189, November, 1847. "*Sol. guinensis*" indicated as type.— Gardner, U.S.G.S., Prof. Paper 199, p. 107, 1948. "Type by original designation: *Solen guineensis guinensis* Chemnitz = *Solen gibbus* Spengler." — Olsson Mollusks of the Tropical Eastern Pacific (Paleo. Res.

Inst.: Ithaca, New York), p. 350, 1961. "Type species by original designation: *Solen guineensis* (=*Solen gibbus* Spengler)."

Type species (by original designation). — "*Sol. guineensis*" [=*Solen guineensis* W. Wood, Gen. Conch., p. 129, 1815, "Inhabits the coast of Guinea." Ref. to Chemnitz, Syst. Conch.-Cab., Bd. 11, pl. 198, fig. 1937, 1795. "bey der Guineischen Küste wohnet."—Also illustrated by Reeve, Conch. Icon., Vol. 19, *Solecurtus*, species 21, pl. 4, figs. 21a, 21b, 1874 (as *Solen caribaeus*). "Hab. America."]

Range. — Late Oligocene or early Miocene (1111) to Recent. Recent in warm temperate and tropical waters, intertidal zone to 73 meters (40 fathoms).

Description. — Shell with elongated, solen-like valves but with the beaks near the middle, the length between three and four times the height. The anterior side is generally a little fuller, the posterior side often slightly depressed especially near its dorsal margin. Both ends of the valves are rounded and generally with a wide open gap. Hinge weak with two small cardinal teeth in the right valve and only one in the left; there are no laterals. The ligament is external and attached to a high nymphal plate. Adductor scars large, placed close to the dorsal margin, and connected across by the pallial line bearing a large open sinus. There is sometimes a slight flexure across the middle of the valves, the surface marked with lines of growth only, white or colored faintly with violet or brown, sometimes rayed. The periostracum is dark brown or straw-colored, generally coarsely wrinkled. (Olsson, 1961.)

Remarks.—Only two species of *Tagelus* havé been reported from beds of Tertiary age in California, one of which occurs in the San Diego Formation. Ten Recent species have been described from eastern Pacific waters between Monterey, California, and Puerto Montt, Chile.

Hesse (1112) mentioned that many Recent species of *Tagelus* are confined to brackish or estuarine waters. Other species, however, including many fossils are associated with strictly marine forms.

The anatomy of some of the Recent species was described by Bloomer (1113).

Subtagelus Ghosh (1114), is a synonym of *Mesopleura* Conrad, with the same type species, *Solen divisus* Spengler. Ghosh believed that this group possessed more primitive anatomical characters than *Tagelus s.s.*

Keen (1145) placed the genus *Tagelus* in the family Solecurtidae rather than in the Garidae (Psammobiidae).

SUBGENUS *TAGELUS* S. S.
Tagelus (Tagelus) californianus Conrad

S[olecurtus]. californianus Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 233, pl. 18, fig. 3, 1837.—Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 296, 1874. "Well at San Diego," "Pliocene."—Dall, Proc. U.S. Nat. Mus., Vol. 1, p. 28, 1878. "well-digging in stratum B^2," San Diego.—Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 265, 1888. "Pl.—San Diego well."—Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 85, August, 1889. Dall's record (1874) cited.—Orcutt, cited by Ellis in Ellis and Lee, U.S.G.S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited.

Tagelus californianus Conrad, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 169, 1903. "Pliocene.—San Diego (Dall)."—I.S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 186, 1924. "Pliocene at San Diego." Also Recent.—Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 384, pl. 21, figs. 2a, 2b, 3 (San Pedro Pleistocene), 1931. Dall's record (1874) cited.—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48, 1944. Dall's record (1874) cited.—Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull., No. 90, p. 79, fig. 45, 1953. Various localitites cited. Recent.

Tagelus (Tagelus) californianus Conrad, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 68, pl. 32, fig. a (Pleistocene in San Diego), 1968. "Pliocene in Balboa Park," San Diego.

Type specimen. — Syntype No. 54.3.14.55, British Museum (Natural History) (see A.M. Keen, Veliger, Vol. 8, No. 3, p. 171, 1966).

Type locality.—"Inhabits muddy salt marshes, in the neighbourhood of Sta. Barbara; common."

Range. — Pliocene to Recent. Recent from Monterey, California, to the Gulf of California and south to Corinto, Nicaragua, possibly to Panama (1116). In bays, estuaries and sloughs, on mud flats or in sandy mud, burrowing to a depth of 42 cm (20 inches) (Fitch).

Occurrence in San Diego Fm. — San Diego well (Dall). Balboa Park (Moore). L.A.M. 305A.

Original description. — Shell oblong-oval, rather thin, convex; extremities equally rounded; basal margin slightly contracted in the middle; beaks central; colour white, tinged with yellowish brown, and marked with direct brown lines in the middle of the valve; epidermis straw colour with radiating wrinkles on the posterior slope. Length, 3 and a half inches. (Conrad.)

Remarks. — This species was reported among the fossils from the San Diego well by Dall in 1874. A fragment of the umbonal portion of a left valve, 10 mm long, from Loc. 305 A (LAM), near the Mexican boundary, is here referred to *Tagelus californianus*. The hinge and a small muscle impression near the dorsal margin are comparable to the corresponding characters of Recent specimens of *T. californianus*.

A large Recent specimen in the collection of the California Academy of Sciences collected by Henry Hemphill at San Diego, is 112 mm long, 31.5 mm high, convexity (both valves together) 20 mm, the pallial sinus extends anteriorly 50 mm from the posterior end of the shell. A specimen collected by E. P. Chace (1117) at Puertecitos, in the Gulf of California, is 128 mm long. The ciliary mechanism of the present species was described by Kellog (1118).

Tagelus californianus often occurs on mud flats in estuaries and sloughs. Orcutt (1119) reported this species at Salton Sea, along with freshwater shells, but specimens of *Tagelus* derived from strata in that area (1120) which we have seen are more nearly referable to *T. affinis longisinuatus* Pilsbry and Lowe.

Tagelus californianus was reported by Reagan (1121) to occur in the Quillayute Formation of Pliocene age in western Washington, but Dall (1112) later examined

the specimen, a fragment, and stated that it was referable to the genus *Tagelus* but he could not identify it specifically.

Tagelus clarki Loel and Corey (1123), described from strata of early Miocene age in California, is shorter and more ovate in outline, the valves are more convex and the posterior dorsal concavity and the umbonal ridge are more pronounced than those of *T. californianus.*

SUPERFAMILY SOLENACEA GRAY (1124)
FAMILY SOLENIDAE GRAY (1125)

Shells usually elongate, sword or razor-shaped, equivalve, usually open and truncated at both ends. Beaks low, terminal or somewhat distant from the anterior umbones, larger in those species having the umbones more distant from the end, the adductor scars large and well marked. Hinge relatively weak with one or two small cardinal teeth, more or less projecting, the ligament external and attached to a short nymph. Surface smooth or sculptured with concentric lines of growth, sometimes with oblique striae or groovings, covered by a coarse brown or straw-colored periostracum. Hinge plate often strengthened or buttressed by a thickened ray. Burrowers in sand. (Olsson, A.A., Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 419, 1961.). Late cretaceous to Recent.

Remarks. — Three genera of this family are represented by fossil forms in the San Diego Formation.

A synopsis of the Solenidae of North America by Dall (1126) appeared in 1899. Recently Habe (1127) published a paper dealing with the Solenidae of Japan. Yonge discussed evolution within the Solenidae (Univ. Calif. Publ. Zool., Vol. 55, No. 9, pp. 421-438, figs. 1-8, 1951).

Key to Genera of Solenidae

A. Beaks terminal or nearly so
  a. Left valve with one cardinal tooth. . . . . *Solen*
  aa. Left valve with two cardinal teeth . . . . . *Ensis*

B. Beaks subcentral or nearly so . . . . . *Siliqua*

GENUS *SOLEN* LINNAEUS

Solen Linnaeus, Syst. Nat., ed. 10, p. 672, 1758. *Solen vagina* included in list of species.—Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 385, 1931. Type (designated by Children): *Solen vagina* Linnaeus.—Eames, Philos. Trans. Roy. Soc. London, Ser. B, Biol. Sci., No. 627, Vol. 235, p. 432, 1951. "Type species. *Solen vagina* Linné, Recent = *S. brevis* Gray; Children, 1822."—Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 420, 1961. "Type species by subsequent designation, Lamarck, 1799 or by Schumacher, 1817, *Solen vagina* Linné."

Type species (designated by Schumacher, Essai Nou. Syst. Test., p. 124, pl. 6, fig. 3, 1817).— *Solen vagina* Linnaeus [Syst. Nat., ed. 10, p. 672, 1758, "Habitat in M. europaeo, Indico." Schumacher cited a reference to "Pl. VI. fig. 3, Chemn. 6 pag. 40. Tab. 4. fig. 28." According to Chemnitz the specimen represented in this figure "Sie wohnet in den ostindischen Meeren." Children (Quart. Jour. Sci. Lit. Art, Vol. 14, p. 83, pl. 4, fig. 26, October, 1823) also designated *Solen vagina* Linnaeus as type of *Solen*. Hanley (Ipsa Linn. Conch., p. 29, 1855) believed that this species was an East Indian form illustrated by Mawe (Linn. Syst. Conchyl., pl. 5, fig. 2, 1823) and this was accepted by Stewart (Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 289, 1930). Hedley (Proc. Linn. Soc. New South Wales, Vol. 38, Pt. 2, p. 275, 1913) believed *Solen vagina* to be a common species of north Queensland which included among its synonyms, *S. truncatus* Mawe *S. brevis* Gray, *S. fonesii* Dunker and *S. jonesii* Conrad. Dodge (Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 45, 1952) recently discussed this species and was convinced that the species name *Solen vagina* is applicable to the Recent European shell. The latter was illustrated by Sowerby in Reeve's Conch. Icon., Vol. 19, *Solen*, species 2, pl. 1, fig. 2, 1874. "Hab. Great Britain." Also Tryon, Struct. and Syst. Conch., Vol. 3, p. 129, pl. 106, fig. 6, 1884.]

Range. — Eocene to Recent. Recent from the intertidal zone to 400 meters (219 fathoms).

Description. — Shell long, straight, dorsal and ventral margins parallel, ovate in cross-section, ends gaping; beaks terminal or usually decidedly anterior; surface smooth; hinge with one tooth in each valve; ligament long, external; anterior muscle impression elongated, posterior one subovate; pallial line extends beyond adductors; sinus short, rather square.

Remarks. — Members of this genus all have long, narrow shells, and the animal burrows in sand or sandy mud to depths of 50 cm at an angel of about 60°. Most of the species live in shallow water.

Two species of *Solen* occur in Californian waters and six species have been recorded occurring in tropical and subtropical west American waters. Eleven or twelve species have been reported from strata of Tertiary age in the western United States. Eight species of this genus have been reported living in Japanese waters by Habe. (1128).

Key to Species of *Solen*

A. Dorsal margin straight; very narrow in proportion to length . . . . . *rosaceus*

B. Dorsal margin slightly arcuate; moderately broad in proportion to length . . . . . *sicarius*

Solen rosaceus Carpenter
Plate 48, Figure 12

Solen sicarius ? var. *rosaceus* Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 536, 638, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 22, 124, 1872.—Carpenter, Ann. Mag. Nat. Hist., Ser. 3, Vol. 15, p. 177, 1865. Reprint in Smithsonian Misc. Coll., No. 252, p. 279, 1872.

Solen rosaceus Carpenter, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 296, 1874. "Well at San Diego."—Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 265, 1888. "San Diego well."—Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 85, August, 1889. Dall's record (1874) cited.—Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 171, 1903. "San Diego well (Cooper)." —Orcutt, cited by Ellis in Ellis and Lee, U.S.G.S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited.—Weymouth, State Calif. Fish Game Comm., Fish Bull. No. 4, p. 50, pl. 15, fig. 3, 1920. San Diego, California, Recent. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 188, 1924. [Not pl. 49, fig. 6] "San Diego well."—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol 2, Pt. 1, p. 48, 1944. Dall's record (1874) of San Diego well.—Fitch, Calif. State Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 76, fig. 42, 1953. "Humboldt Bay, California, to Mazatlan, Mexico." [Not the record "Humboldt Bay, California."]—K.V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 114, 1958. [Discussion of Carpenter's specimens.]—Pohlo, Veliger, Vol. 6, No. 2, pp. 98, 100 figs. 1, 2, 4, 1963. [Morphology and mode of burrowing.]

Type specimen.—"The type of this species has not been found." (Palmer. 1958.)

Type locality. — Cited as from "neighborhood of Sta. Barbara" and "The region between S. Diego and S. Pedro," California (Carpenter, 1864). "Hab. Sta. Barbara (Jewett; S. Pedro (Cooper)" (Carpenter, 1865). "Santa Barbara or San Pedro, California (type)" (Palmer, 1958).

Range. — Pliocene to Recent. Recent, from Santa Barbara, California, to Punta Peñsaco and San Felipe in the Gulf of California and south to Mazatlan, Sinaloa, Mexico. Intertidal zone to 46 meters (25 fathoms). "Usually found at depths from a few inches to a foot or more in sandy mud of sheltered bays, sloughs and estuaries" (Fitch).

Occurrence in San Diego Fm. — San Diego well (Dall). C.A.S. 1182. S.D. 5006.

Original description. — Straight, narrower, longer, smaller; glossy, rosy. (Carpenter, 1864.)

Supplementary description. — S. testa *S. sicario* simili, sed minore; multo angustiore, elongata, recta, extus et intus rosacea; epidermide tenui, valde nitente. Long. .27, lat. .5, alt. .32 poll. (Carpenter, 1865.)

Remarks. — A cast of a small *Solen* collected at Loc. 4, (SD), on Mount Soledad, was identified as *S. rosaceus* by Mrs. Kate Stephens. The posterior end is lacking but the remainder is 29.2 mm long and 7.3 mm high. Another less perfectly preserved cast from the Loc. 1181 (CAS), also from Mount Soledad, is 21 mm long. The straight dorsal margin and the ratio of height to length of both casts are comparable to Recent specimens of *S. rosaceus*. A portion of a cast, 15 mm long, collected at Loc. 34 (SD), northeast corner of India and Thorn streets, San Diego, may be referable to this species.

The shell of *Solen rosaceus* differs from that of *S. sicarius* Gould in that it is longer in proportion to the height and also in that the dorsal margin is straight rather than distinctly arcuate in outline.

Recent shells of *S. rosaceus* have rosy coloration rather than white as in Gould's species. Large specimens are often about 70 mm long. Johnson and Snook mentioned a very large specimen 75 mm long, 14 mm high and 19 mm in diameter.

It appears probable that records of this species from Miocene strata are referable to *Solen perrini* Clark. That species has a straight dorsal margin but has a thicker shell which also is much higher in proportion to the length than that of *S. rosaceus*. Clark's species was considered by Grant and Gale to be a subspecies of *S. sicarius*.

Solen tanozawaensis Nomura (1129) described from Miocene strata in Japan was compared by its author with *S. rosaceus* from which it differs in the more arcuate dorsal margin.

Weymouth (1920) mentioned concerning *S. rosaceus*, "it is interesting as being capable of a kind of 'swimming' though habitually found in burrows."

Solen sicarius Gould
Plate 49, Figure 7

Solen sicarius Gould, Proc. Boston Soc. Nat. Hist., Vol. 3, p. 214, May, 1850. — Gould, U. S. Explor. Exped. (Wilkes), Vol. 12, p. 387, 1852, Atlas, p. 13, pl. 33, figs. 501, 501a, 501b, 1856. — Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 204, 1909. Quillayute Formation, western Washington, Pliocene. Also "Purisima San Diego."—J.P.Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 174, 182, 1912. "San Diego - Purisima." — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 281, pl. 26, fig. 1, pl. 50 (chart), 1918. "Range. — Vancouver Island to San Quentin, Lower California (Orcutt)."—Weymouth, State Calif. Fish Game Comm., Fish Bull. No. 4, p. 50, pl. 15, fig. 2, 1920. British Columbia to Southern California, Recent. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 188, pl. 49, fig. 1; pl. 18, fig. 1, 1924. Various localities, Pliocene to Recent. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 385, pl. 21, fig. 4, 1931. Late Miocene to Recent. — Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 77, fig. 43, 1953. "Range: British Columbia to San Quintin Bay, Baja California."

Type specimen. — Holotype No. 11876, United States National Museum.

Type locality. — "Hab. Straits of De Fuca, Oregon." [Washington.]

Range. — Late Miocene (Briones; Santa Margarita; San Pablo) to Recent. Recent from Vancouver Island, British Columbia, to San Quintín Bay, Lower California, Mexico; littoral zone to 124 meters (68 fathoms), burrowing in mud or muddy sand to a depth of 15 to 20 inches

in bays, estuaries and sloughs.

Occurrence in San Diego Fm. — C.A.S. 1181, 1402, 28891. L.A.M. 305, 305A, 319. S.D. 4, 417.

Original description. — T. transversa, oblonga, retrorsum angustata, subfalcata, epidermide crasso, nitido, corneo induta, anticè obliquè truncata, posticè rotundata: valvis valdè excavatis, undulatis, areis triangularibus indistinctè partitis; margine dorsali recto; m. ventrali arcuato; natibus terminalibus: cardo dente triangulari, erecto, recurvo in utrâque valvâ instructa. Long. 3 1/2; lat. 7/20; alt. 9/10 poll. (Gould.)

Remarks. — One of the best preserved specimens of this species in the collections from the San Diego Formation, lacking only small portions of the ventral area, is one in the San Diego Society of Natural History from the south slope of Mount Soledad. It is 62.2 mm long, 14.9 mm high, the convexity (both valves together) 10.4 mm. This and other specimens from Balboa Park, in all observed characters, resemble Recent specimens of *Solen sicarius*. Large Recent specimens from adjacent waters attain a length of 75 mm and a height of 18 mm and specimens 88 mm long have been reported from Morro Bay, California. Fragments of this species are present from several localities near the Mexican boundary.

The shell of this species differs from that of *Solen rosaceus* in the larger size, gently arcuate rather than straight dorsal margin and on Recent specimens the color is greyish rather than rose.

Solen perrini Clark (1130), described from strata of late Miocene age, has a straight dorsal margin similar to that of *S. rosaceus*, but the flexure on the anterior end is more pronounced than on *S. sicarius*. This form is said to attain a length of 153 to 204 mm (six to eight inches) and a height of 25 to 38 mm (1 to 1 1/2 inches).

Solen clallamensis Clark and Arnold (1031) described from beds of middle Miocene age at Clallam Bay, Washington, bears a similarity to *S. sicarius* but it was said to differ in the more rounded anterior end and in that the anterior sulcus is situated farther from the end of the shell.

Small specimens about 40 mm in length from the Eugene Formation in western Oregon, believed to be of Oligocene age, were referred to *S. sicarius* by Hickman (1132).

"*Solen* cf. *siscarius* Gould" was cited as occurring in Formosa by Kuroda (1133), but apparently there is doubt concerning the identification because Kuroda and Habe (1134) include it with question in a check list of Japanese species. The general shape of *S. krusensterni* Schrench as illustrated by Hirase (1135) is similar to that of *S. sicarius*.

The record of *Solen sicarius* from a Quaternary terrace in Ecuador (1136) is referable to some other species.

GENUS *ENSIS* SCHUMACHER

Ensis Schumacher, Essai nouv. Syst. Hab. Vers Testacés, p. 143, 1817. Species cited, "*Ensis magnus*" [Schumacher], pl. 14, fig. 1. Also mentioned were, "*Solen ensis* Lin. *Solen siliqua* Chemm. 6. pag. 44. Tab. 4, fig. 29."—Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 5, pp. 950, 954, 1900. "Type *S. magnus* Linné." — Cossmann and Peyrot, Act. Soc. Linn. Bordeaux, Tome 63 (Conch. Néogéne de L'Aquitaine, Tome 1), Livr. 1, p. 150, 1909. "G.-T.: *Solen ensis* Linné." — Gardner, U. S. G. S., Prof. Paper 142-E, p. 217, 1928. "Type *Ensis magnus* Schumacher."

Type species (by tautonomy, and by subsequent designation by Herrmannsen, Indic. Gen. Malcozoo., Vol. 1, p. 423, 1846).—"Typus: *Solen ensis* Linn." [Syst. Nat., ed. 10, p. 672, 1758. "Habitat in M. Mediterraneo, Anglico." Ref. to "List, angl. app. t. 2. f. 9" and "Argenv. conch. t. 27. f. L? Also illustrated by Sowerby in Reeve's Conch. Icon., Vol. 19, *Solen*, species 3, pl. 1, fig. 3, 1874. "Hab. Great Britain." — Van Urk, Basteria, Vol. 28, No. 1 and 2, p. 37, pl. 1, fig. 4, 1964. "North Sea-Mediterranean." For discussion of this species see Dodge, H., Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 34-35, 1952.]

Range.—Eocene; Miocene to Recent. Recent, world wide in warm temperate and tropical waters, in soft inshore sands and muds, but also offshore (off Florida) to a depth of 91 meters (50 fathoms), and perhaps deeper.

Description. — Valves thin, scabbard-shaped, slightly gaping, usually somewhat arcuate; umbones flattened, subterminal; ligament external, opisthodetic; hinge of right valve armed with one vertical and one horizontal lamelliform cardinal, that of the left valve with two proximate vertical cardinals and one horizontal; anterior adductor impression conspicuous, elongated in the general direction of the major axis; pallial line rather distant from the ventral margin, sinuate posteriorly (Gardner, 1928.)

Remarks. — Some authors place the genus *Ensis* in the family Cultellidae.

The presence of *Ensis* in beds of Tertiary age in western North America is reported here for the first time. However, it has been reported from beds of Pleistocene age in this region by several authors. One species now lives in warm temperate waters in this region and two in southern tropical waters. This genus is known to occur in Florida and in Europe in strata of Miocene age.

Holmes (1137) gave an excellent discussion of the three Recent British species including their ecology and more recently Van Urk (1138) discussed the European species of *Ensis*. Some species of *Ensis* are described as able to move about very quickly in their burrows.

Ensis myrae Berry
Plate 57, Figures 7, 19

Ensis californicus Dall, I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 189, pl. 49, fig. 6, 1924. "San Pedro." [The plate and figure are erroneously cited under the caption to *Solen sicarius* Gould, p. 188.]

Not *Ensis californicus* Dall, 1899.

Ensis myrae S. S. Berry, Trans. San Diego Soc. Nat. Hist., Vol. 11, No. 15, pp. 398, 399, figs. 3, 4, August 14, 1953.

Type specimen. — No. 7582, Stanford University.

Type locality. — "San Pedro Bay, California; mainly cast up by storms in the vicinity of Terminal Island."

Range. — Middle Pliocene to Recent. Recent from Monterey, California, to Islas Los Coronados, Lower California, in 14 to 46 meters (8 to 25 fathoms) to 91 meters (50 fathoms) according to Valentine and Mead

(Univ. Calif. Publ. Geol. Sci., Vol. 40, No. 1, p. 26, 1961).

Occurrence in San Diego Fm. — C.A.S. 28889, 28892. L.A.M. 107, 305, 305A, 318, 319.

Original description. — Shell of moderate size and slenderness, rather strongly falciform; valves narrowing slightly and rather sharply and squarely truncate in front, more rounded and narrowing a little more steadily and decidedly posteriorly. Hinge-plate strongly anterior in position, small and comparatively short; right major cardinal compressed, squarish in profile, strongly projecting; right posterior cardinal slender, short (appreciably less than one-tenth the length of the shell), laminar, terminating in a short free flange; left major cardinals strongly unciform and considerably heavier than that in the right valve; inner left posterior cardinal generally similar to its mate of the right valve, the weaker outer cardinal closely adnate to the shell margin. Exterior of shell mostly with a somewhat silky sheen due to the numerous fine growth-striae underlying the thin shining Sayal Brown to Mikado Brown periostracum; in adult shells the periostracum is usually rubbed away in a blade-shaped swath extending from the beaks to the posterior margin, this area being white except for some ruddy or purplish coloring, especially along the edges of the area and in the incremental rest-marks, where the Deep Rose Pink or Vinaceous tinting of the interior may shine through. Maximum longitude, 81.3 mm., altitude, 11.9 mm., percentage of altitude to length, 14.6 mm., diameter 5.8 mm. (Berry.)

Remarks. — One fairly well preserved right valve of an *Ensis* and many fragments from Locs. 305 and 305A (LAM), and fragments from Loc. 319 (LAM), all from near the Mexican boundary, are present in the collections of the Los Angeles County Museum. These agree in all observable details with Recent shells of *Ensis myrae* Berry. The large right valve is 63.9 mm long and 10 mm high. A cast retaining portions of the shell material, from Loc. 28892 (CAS), also from near the Mexican boundary, appears to be referable to *E. myrae.*

This species was described as differing from *E. californicus* Dall (1139) in the greater size, less slender outline, greater arcuation, squarish rather than rounded anterior end, the pallial line nearer the margin, and in minor details of the hinge.

We have not studied a series of specimens of *E. californicus* but the single valve from Manzanillo, Mexico, reported by Hertlein and Strong (1140), 60.5 mm long, and 7.3 mm high, has an outline more slender than that of *E. myrae* but the anterior end much less rounded than that shown in Berry's (1141) drawing of a specimen of *E. californicus* from San Felipe, in the Gulf of California.

The ratio of height to length of the type of *E. californicus* is 12.1, of the left valve reported from Manzanillo, Mexico, 11.7, that of the type of *E. myrae* 14.6 and that of the right valve from the San Diego Formation, 15.6.

The only other species of *Ensis* described from eastern Pacific waters is *Ensis tropicalis* Hertlein and Strong (1142), the outline of which is only slightly arcuate and in this character it resembles some species of *Solen.*

Ensis myrae, at times, has been mistaken for *Solen rosaceus.* The nearly straight anterior end of the pallial line and the gently obliquely sloping anterior retractor muscle impression are features which aid in separting even fragments of the anterior end (when the interior is exposed) from Carpenter's species. The corresponding muscle impression on *S. rosaceus* is wider and parallel to the dorsal margin of the valve.

GENUS *SILIQUA* MEGERLE VON MÜHLFELD

Siliqua Megerle von Mühlfeld, Gesell. f. Naturfor. Freunde zu Berlin, p. 44, 1811. Sole species: *Siliqua radiata* Linnaeus. Ref. to "Linn. Syst. Nat. Gen. 304. Sp. 6" and "Chemn. Conch. 6, t. 5. f. 38. -40." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 386, 1931. Type, *Solen radiatus* Linnaeus.

Leguminaria Schumacher, Essai Nouv. Syst. Hab. Vers Test., p. 126, 1817. Type (by monotypy): *Leguminaria costata* Schumacher, p. 126, pl. 7, fig. 1 [= *Solen radiatus* Linnaeus].

Machaera Gould, Invert. Massachusetts, p. 32 1841. *Solen radiatus* Linnaeus and other species cited.

Not *Machaera* Cuvier, 1832.

Type species (by monotypy). — "*Siliqua radiata*" Linnaeus [= *Solen radiatus* Linnaeus, Syst. Nat., ed. 10, p. 673, 1758. "Habitat in O. Asiatico." Ref. to "Rumph. mus. t. 45. f. E."; "Gault. test. t. 91, f. B."; "Argen. conch. T. 25. f. P." Illustrated by Sowerby in Reeve's Conch. Icon., Vol. 19, *Cultellus*, sp. 13, pl. 4, fig. 13, 1874. "Hab. Sumatra." For a discussion of this species see Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, art. 2, p. 36, 1952.]

Range. — Late Cretaceous?; Eocene to Recent. Recent from the intertidal zone to about 55 meters (30 fathoms).

Description. — Shell oblong, length about three times as great as the height, somewhat compressed, smooth, ends rounded, gaping, beaks about one third to one fourth the distance from the anterior end; interior of valves with a flattened rib posterior to anterior muscle impression, extending from beneath the beaks to the ventral margin; hinge with 2 small, close cardinals in the left valve and one in the right; pallial sinus large, short, rounded.

Remarks. — *Siliqua alisoensis* Packard (1143) was described from strata of late Cretaceous age in the Santa Ana Mountains in southern California. An internal rib was present on the anterior portion of the shell. The hinge was not described and there may be doubt as to whether this species is referable to *Siliqua* or to some similar genus *Leptsolen* Conrad, a Cretaceous genus, also has an internal rib. *Senis* Stephenson, which resemble *Siliqua* in external features, is said to lack hinge teeth. The genus *Siliqua* has been recorded from strata of Eocene age in Texas (1144) and in Japan (1145). Gardner (Univ. Texas Bull. 3301, p. 188, 1935) reported "*Siliqua?* sp." from the upper Midway Group now believed to be of Paleocene age.

No species of *Siliqua* have been reported from the early Tertiary strata of California but the genus is definitely known to occur from late Miocene (Briones) to Recent. It has been reported from western Oregon in beds of middle Miocene age and in northern California in strata of late Miocene age and in beds of Pliocene age.

Siliqua is essentially an inhabitant of cool waters.

Five species are known to occur in west American waters between the Arctic Ocean and Todos Santos Bay, Lower California. According to Paul Bonnot (1146), *S. patula* lives in sand close to the surface, the hinge toward the sea.

This genus was included in the family Cultellidae by Keen in 1969.

Siliqua lucida Conrad
Plate 49, Figure 2

S[olecurtus]. lucidus Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 231, pl. 17, fig. 8, 1837.
Siliqua lucida Conrad, I.S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 189, pl. 52, fig. 2, 1924. "Range. Monterey, California, to Todos Santos Bay, Lower California. In the Pleistocene at San Pedro and San Diego, California."—Johnson and Snook, Seashore Animals of the Pacific Coast (Macmillan and Co.: New York), pp. 458, 460, fig. 458, edit. 1935. Monterey, California, to Lower California. — Morris, A Field Guide to Shells of the Pacific and Hawaii (Houghton Mifflin Co.: Boston), p. 55, pl. 14, fig. 6, 1952. Bolinas Bay, California, to Mexico.—Hertlein, Bull. South. Calif. Acad. Sci., Vol. 60, Pt. 1, pp. 14-15 (in text), pl. 5, figs. 4, 5, 6, 1961. From breakwater at North Island, Los Angeles County, California, Recent.

Type specimen. — Syntypes, four valves, Nos. 61.5. 20.133 (3 valves) and 57.8.14.2 (single valve), British Museum (Natural History) (A. M. Keen, Veliger, Vol. 8, No. 3, p. 170, 1966).

Type locality. — "Inhabits the sand-beach, near Sta. Barbara; uncommon."

Range. — Late Miocene (Briones) to Recent. Recent from Bolinas Bay, California, to San Quintín Bay, Lower California, Mexico, on sandy beaches and to the depth of 46 meters (25 fathoms).

Occurrence in San Diego Fm. — L.A.M. 107, 305, 305A, 319. S.D. 83. U.C.L.A. 1386.

Original description. — Shell oblong, oval, compressed, thin, fragile, translucent; posterior extremity nearly direct, truncated; colour blueish, with purple concentric zones, and two oblique pale rays on the posterior side; interior rib nearly direct. (Conrad.)

Remarks. — One specimen retaining much of the shell and four others less perfectly preserved were collected by Frank Stephens on Reynard Way in San Diego. The largest specimen (incomplete) is 36.5 mm long. The shape and observable characters of this and the accompanying specimens are comparable to Recent specimens of *Siliqua lucida* of the same size. Recent specimens 55 mm long have been reported from Morro Bay, California. Two imperfect casts from Kensington Park, San Diego, may be referable to this species. Two small single valves about 18 mm long and a left valve 28.5 mm long, from Loc. 107 (LAM), appear to be referable to this species. The anterior portion of a left valve, about 18 mm long from Loc. 305 (LAM), agrees in shell characters with the corresponding portion of a Recent valve of *S. lucida*. Many fragments, probably referable to this species, are present in the collections of the Los Angeles County Museum from Locs. 107, 305, 305A, and 319.

The shell of *Siliqua lucida* is separable from that of young specimens of *S. patula* in that it is smaller and much more elongate, the ventral margin is more arcuate, the anterior end is shorter and the posterior end is somewhat more truncated. The shell of *S. lucida* is very thin and the exterior of live specimens is gray tinged with violet, whereas that of *S. patula* is covered with a shiny, light brown periostracum. The interior rib of the present species is nearly vertical rather than inclined anteriorly and in this character it more resembles the northern *S. media* Sowerby.

Siliqua sloati Hertlein (1147), a Recent species described from off California, differs from *S. lucida* in the more roundly pointed posterior end and in the less expanded posterior dorsal area which is not bordered by a distinct groove.

An intensive study of *Siliqua patula* Dixon, a large form of commercial value, was made by Weymouth, et al. (1148) According to those authors, *S. patula* attains a maximum age of 19 years. Large specimens are 170 mm long.

SUPERFAMILY MACTRACEA BOWDICH (1149)
FAMILY MACTRIDAE BOWDICH (1150)

Shell roundly trigonal or oblong; closed or slightly gaping; lunule and escutcheon not well defined; surface usually marked only with lines of growth, rarely with strong concentric sculpture; beaks inclined anteriorly; ligament opisthodontic, short; resilium triangular or ovoid and situated in a deep pit, usually on a downward projecting hinge-plate (chondrophore) which is posterior to the cardinals; hinge of left valve usually with one bifid V-shaped cardinal, sometimes with accessory shelly processes, and usually with an anterior and a posterior lateral tooth; all these fit into sockets or paired laminae in the right valve; pallial sinus well developed; adductor impressions subequal, peripheral. Cretaceous to Recent.

Remarks. — This family includes a number of gen-

Key (1158) to Genera and Subgenera of Mactridae

A. Shell broadly gaping posteriorly; outline ovately rectangular . . . . . *Tresus*

B. Shell narrowly gaping or closed; outline usually ovately subtrigonal.
  a. Chondrophore separated from resilium by a shelly lamina . . . . . *Mactra* (1159)
  aa. Chondrophore not separated from resilium by a shelly lamina.
    b. Lateral teeth moderately long; beaks nearly centrally situated . . . . . *Spisula* s. s.
    bb. Lateral teeth short; beaks more anteriorly situated . . . . (subgenus) *Mactromeris*

era and subgenera. About a dozen species have been recorded from Pliocene strata of California, Oregon, and Washington. Eleven species occur in marine waters between the Bering Sea and San Diego, California, and 24 species have been recorded living in tropical and subtropical waters of the western Americas.

The family Mactridae has been the subject of special studies by Gray (1151), Dall (1152), and Lamy (1153). A paper by Packard (1154) deals with Mesozoic and Cenozoic Mactridae of western North America, chiefly north of Mexico and papers by Hertlein and Strong (1155), by Keen (1156), and by Olsson (1157) contain discussions of a number of tropical west American species.

GENUS *SPISULA* GRAY

Spisula Gray, Mag. Nat. Hist., New Ser., Vol. 1, p. 372, July, 1837. Many species cited including "*Spisula sólida*; Mactra sólida Montague" (p. 374).—Dall, Trans. Wagner Free. Inst. Sci., Vol. 3, Pt. 4, p. 895, 1898. — Lamy, Jour. de Conchyl., Vol. 63, No. 4, p. 291, 1918. Type: *Mactra solida* Linnaeus. -- Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 393, 1931. Type: *Mactra solida* Linnaeus as indicated by Gray, 1847. — Olsson, Mollusks of the Tropical Eastern Pacific Paleo. Res. Inst.: Ithaca, New York), p. 326, 1961. Type as indicated by Gray.

Type species (designated by Gray, Proc. Zool. Soc. London for 1847, p. 185). — "*M. solida*". [= *Cardium solidum* Linnaeus, Syst. Nat., Ed. 10, p. 681, 1758. "Habitat in O. Anglico." Ref. to "Bonan. recr. 3. t. 51"; "Rond. test. 1. c. 7"; "List Angl. 174, t. 4. f. 24". — Lamy, Jour. de Conchyl., Vol. 63, No. 4, p. 295, figs. of hinge (p. 292), 1918. (With synon.). —Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 75, 1952.]

Key to Species of *Spisula*

A. Valves compressed; adult shell usually less than 70 mm long.
  a. Shell subtrigonal; beaks nearly central . . . . . *planulata*
  aa. Shell elongately trigonal; beaks decidedly anterior . . . . . *falcata*

B. Valves inflated; adult shell usually more than 70 mm long.
  a. Beaks posterior to the middle of valves . . . . . *hemphilli*
  aa. Beaks anterior to the middle of valves.
    b. Posterior flexure distinct; ovately elongate in outline or ovately subtrigonal. . . *catilliformis*
    bb. Posterior flexure indistinct; very elongate in outline, the beaks more anteriorly situated . . . . . *mercedensis*

Range. — Middle Eocene to Recent. Recent from the littorial zone to 110 meters (60 fathoms); occasionally deeper.

Original description. — Shell ovate, trigonal, subangular at each end. Hinge and lateral teeth as in Mactra; but hinge tooth of left valve very small. Siphonal inflection ovate, distinct. Ligament just within the cardinal edge, over the top of the cartilage, and not separated from it by any shelly plate; and partly hid from view by the hinge margin. (Gray.)

Remarks. — The generic and subgeneric assignment of many species to *Mactra* or to *Spisula*, especially fossil forms, is doubtful due to the difficulty of detecting whether or not the resilium is separated from the ligament by a shelly lamina. Five species which occur in the San Diego Formation are referable to *Spisula* (1160).

Eight species referred to *Spisula* have been reported as occurring in strata of Pliocene age in western United States. Six species are known to occur in marine waters between the Bering Sea and San Diego, California.

[*Mactra albaria* Conrad]

Mactra albaria Conrad, Amer. Jour. Sci., Ser. 2, Vol. 5, p. 432, fig. 4, 1848. Reprint by Dall, U. S. G. S., Prof. Paper 59, p. 150, fig. 4, 1909. — Dall, cited by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 63, 1919.

Type specimen.—"Holotype: Missing and presumed lost." (Moore, Ellen, U. S. G. S., Prof. Paper 419, p. 83, 1963.)

Type locality.—"Near Astoria. . .Teriary." [Middle Miocene.]

Range. — Miocene.

Occurrence in San Diego Fm. — "About 3 1/4 miles east of Chula Vista and 1 1/4 miles southeast of Bonita the north wall of a small canyon, locally known as Fossil Canyon. . .about 300 feet above sea level." (Dall, cited by Ellis in Ellis and Lee.)

Remarks. — The only record of the occurrence of this species in the San Diego Formation is that of Dall cited by Ellis. *Mactra albaria* was originally described from Astoria, Oregon, where it occurs in beds of middle Miocene age. It has been recorded as occurring in beds of Pliocene age in northern and central California, as well as in Oregon and Washington, but it has not been recorded from Pliocene strata in the Los Angeles basin nor south of there.

Spisula albaria var. *coosensis*. (1161) from the Pliocene of Coos Bay, Oregon, was described by Howe. This form attains a large size and lacks the pronounced angulation such as occurs on *S. albaria* from the beak to the posterior (1162) ventral margin. Howe also mentioned differences in the hinges of the two forms. Those from Astoria "show the left cardinal to extend uniformly from the beaks to the edge of the chondrophore, while in var. *coosensis* the left cardinal extends only two-thirds of this distance." There also is said to be a difference in the characters of the hinge of the right valve of the two forms. Weaver (1163) cited the range of *S. albaria* as "Upper Miocene to Recent", but so far as known it does not occur in the post-Miocene fauna. It appears likely that Pli-

ocene records of *S. albaria* may be referable to *S. a. coosensis.*

In view of the fact that neither *Spisula albaria* nor *S. a. coosensis* has been observed in any of the collections from San Diego and as the sole record is that of Dall in a general faunal list by Ellis, we are inclined to consider this to be an invalid record for the San Diego Formation.

SUBGENUS *MACTROMERIS* CONRAD

Mactromeris Conrad, Amer. Jour. Conch., Vol. 3, Cat. Mactridae, ap. p. 45, January 2, 1868. Seven species (including several synonms) cited of which *S. ovalis*, Gould", is first. — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 207, 1930. "Type species *Mactra ovalis* Gould, designated by Stoliczka." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 394, 1931. "Type (by subsequent designation, Dall, 1898), *M. polynyma* Stimpson." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 323, 1961. "Type species by subsequent designation, Dall, 1898, *Spisula ovalis* Gould (= *Mactra polynyma* Stimpson)."

Symmorphomactra Dall, Nautilus, Vol. 8, No. 4, p. 41 August, 1894. Sole species. "*Spisula (Symmorphomactra) falcata* Gld., 1850. Comox, Br. Col. to San Pedro, Cala."

Type species (designated by Stoliczka, Mem. Geol. Surv. India, Palaeont. Indica, Ser. 6, Vol. 3, Pelecypoda, p. XVI, 1871. — "*St. ovalis*, Gray," (on p. 53 cited as "*Standella ovalis*, Gould") [= *Mactra ovalis* Gould, Amer. Jour. Sci., New Ser., Vol. 38, p. 196, 1840. [No locality cited.] — Gould, Invert. Massachusetts, p. 53, pl. 3, fig. 32, 1841; ed. by Binney, 1870, p. 75, fig. 32. (Not *Mactra ovalis* G. B. Sowerby, 1818. Crag, Pliocene of England). Gould's species was renamed *Mactra polynyma* by Stimpson, Smithsonian Misc. Coll., Vol. 2, Art. 6, No. 3, p. 3, 1860. For synonymy of this species see Lamy, Jour. de Conchyl., Vol. 63, No. 4, p. 319, hinge illustrated p. 198, 1917.]

Range. — Miocene to Recent. Recent in boreal and warm temperate waters. One or two species in tropical west American waters have been referred to *Mactromeris.*

Description. — Shell of moderate or large size; beaks more anteriorly placed than in *Spisula s. s.*; hinge of left valve with small accessory lamina posterior to the cardinal tooth, right valve with anterior cardinal separate from lower anterior lateral; lateral teeth smooth. (Adapted from Lamy, and Grant and Gale.)

Remarks. — The hinges of many of the groups of Mactridae are quite similar. The group segregated under *Mactromeris* possess a hinge similar in general features to *Spisula s. s.* as mentioned by Stewart. They differ in that the laterals are proportionately shorter, the beaks are more anteriorly situated and the pallial sinus is longer.

A subgenus of *Spisula*, *Symmorphomactra*, was proposed by Dall in 1894 with the sole species *Spisula (Symmorphomactra) falcata* Gould. This subgenus was described as "teeth of *Mactrotoma*, *s. s.*, hinge of *Spisula.*" The following year Dall (1164) did not cite this category in his synopsis of the Mactridae. In 1921 he (1165) placed *Spisula falcata* in the subgenus *Hemimactra*, section *Mactromeris*, and referred only one species, *S. planulata* Conrad, to *Symmorphomactra.*

Some authors consider *Symmorphomactra* to lack systematic value. The current classification of genera and subgenera of west American Mactridae is not entirely satisfactory. For the present we have *S. falcata* and *S. planulata* in *Mactromeris.*

The hinge of *Hemimactra* Swainson (1166) differs from that of *Mactromeris* in that the cardinals are almost obsolete and the laterals are transversely striated.

Recent species of *Mactromeris* are almost restricted to the region encompassed by boreal to warm temperate waters along both coasts of North America and Japan. There are about six species living in west American waters and about the same number of species have been described as fossils in that region.

Spisula (Mactromeris) catilliformis Conrad
Plate 54, Figures 5, 7

Spisula catilliformis Conrad, Amer. Jour. Conch., Vol. 3, No. 2, p. 193, September 5, 1868. — Conrad, Amer. Jour. Conch., Vol. 5, Pt. 2, p. 108, pl. 13, fig. 1, October 7, 1869.

Mactra (Spisula) catilliformis Conrad, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 62 ("Pacific Beach," "Pliocene"), p. 176 "Pliocene. — San Diego (Arnold)", pl. 19, fig. 5 ("Upper San Pedro series, San Pedro"), 1903.—Arnold, U.S.G.S., Prof. Paper 47, p. 28, 1906. "San Diego formation as developed in the type section at Pacific Beach north of San Diego." — Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 202, 1909. "Purisima-San Diego." — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 398, pl. 23, figs. 4 and 10 (from Etchegoin), 1931. "Pacific Beach, San Diego (Arnold, 1903.)"

Mactra catilliformis Conrad, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 172, 1912. "San Diego-Purisima." Pliocene.

Spisula catilliformis Conrad, Packard, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 15, p. 285, pls. 17, 18, 19, May 1, 1916. Middle Miocene to Recent. — Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 282, pl. 27, figs. 1, 2; pl. 24, fig. 2, 1918. "Range. — Straits of Juan de Fuca, Washington, to San Diego, California." I.S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 194, pl. 24 (reproduction of pl. 17 of Packard, 1916), 1924. "Pliocene at San Diego." Also other occurrences. Recent from "Neah Bay, Washington, to San Diego, California."—Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 87, fig. 53, 1953. "Range: San Francisco Bay to San Diego Bay." —Abbott, American Seashells (D. Van Nostrand Co.: New York), p. 448, fig. 90c, 1954. Washington to Ensenada, Lower California

Type specimen. — Location unknown to the present authors.

Type locality. — "Inhabits Panama" [As stated by Dall (Nautilus, Vol. 7, No. 12, p. 137, pl. 5, fig. 3, 1894), this species was "erroneously stated to have come from Panama." In this paper Dall cited the distribution as "Neeah Bay to San Diego, Cala."]

Range.—"cf." Early and middle Miocene (Vaqueros and Temblor formations); late Miocene to Recent. Recent, from Neah Bay, Washington, to San Quintín Bay, Lower California, in 18 to 73 meters (10 to 40 fathoms), occasionally in shallower water. "Lives in fine sand or firm sandy mud in bays, sloughs and estuaries as well as more quiet protected areas along the outer coast" (Fitch).

Occurrence in San Diego Fm. — C.A.S. 1140, 1182, 1400. L.A.M. 104, 107, 305, 305A, 309, P.87, A-1323.

Original description. — Suboval, inequilateral; anterior side slightly flattened or contracted; posterior side with an oblique shallow groove or fold; lines of growth coarse and prominent; lunule very long, elliptical; ventral margin tumid posteriorly; cardinal pit oblique, large; pallial sinus extending beyond the middle of the valve. Length 4 5/8 inches; height 3 7/8 inches. (Conrad.)

Remarks. — A number of specimens of *Spisula catilliformis*, in various states of preservation, are present in the collections from the San Diego Formation. There is variation in the outline of a series of specimens, some are decidedly more triangular than others. A large cast, retaining some shell material, from Loc. 107 (LAM), at the end of Arroyo Drive, San Diego, is 129.5 mm long and 99 mm high. Another smaller cast from the same locality is 92 mm long, 71 mm high, convexity (both valves together), 47 mm. A specimen retaining most of the shell material from Loc. 305 (LAM), near the Mexican boundary, is 124 mm long, 102 mm high, convexity (both valves together) 62 mm. The beaks are approximately 57 mm from the anterior end of the shell. A Recent specimen, in the collections of the California Academy of Sciences, from Halfmoon Bay, California, is 134 mm long, 104 mm high, convexity (both valves together) approximately 61 mm, beaks situated about 49 mm from the anterior end of the shell, and the pallial sinus extends forward about 49 mm from the posterior end of the shell. A smaller specimen from Loc. 37138 (CAS), Monterey, California, is 109 mm long, 81 mm high, convexity (both valves together) 50 mm, the beaks are about 45 mm from the anterior end of the shell. The hinges as well as the other shell characters of the fossils are all comparable to Recent specimens of the same size.

The fossils from beds of Pliocene age in the Santa Maria district, California, cited by Woodring (1167) under the name "*Spisula* cf. *S. catilliformis* Conrad" were said to refer to the short, rounded form described from that area by Arnold under the name of *Spisula catilliformis* var. *alcatrazensis* (1168). He mentioned, however, that no Recent specimens of *S. catilliformis* are as short as the fossils from Santa Maria.

Spisula (Mactromeris) cf. *S. (M.) falcata* Gould
Plate 54, Figure 8; Plate 57, Figure 12

The following references, type locality, range and description refer to typical *S. falcata.*

Mactra falcata Gould, Proc. Boston Soc. Nat. Hist., Vol. 3, p. 216, May, 1850. — Gould, U. S. Explor. Exped. (Wilkes), Vol. 12, p. 393, 1852, Moll., Atlas, p. 13, pl. 34, figs. 506, 506a, 506b, 1856. — Gould, Otia Conch., p. 76, 1862. [Original description reprinted.]

Spisula planulata Conrad, Packard, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 15, p. 293, pl. 16, figs. 3a, 3b, 3c, 1916.

Not *Mactra planulata* Conrad, 1837.

Spisula falcata Gould, I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 60, pl. 17, figs. 1-3, 1924. [Reproductions of Gould's original illustrations, figs. 506, 506b.] "Puget Sound to Cortez Bank and the Coronado Islands, Mex." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 195, pl. 20, figs. 1-3, 1924. [Reproduction of Gould's original illustrations, 506, 506b.]

Type specimen. — No. 5893, United States National Museum.

Type locality. — "Hab. Puget Sound, Oregon." [Washington.]

Range. — Middle Pliocene (1169) to Recent. Recent from Queen Charlotte Islands, British Columbia, to San Diego, California, and Cortez Bank, and Coronado Islands, Mexico, in 4 to 50 meters (2 to 24 fathoms).

Occurrence in San Diego Fm. — L.A.M. 305A.

Original description of *Mactra falcata.* — Testa magna, transversa, ovatotrigona, inequilateralis, convexiuscula, modice hians, albida, epidermide fulvo, nitido, concentricè rugoso induta; umbonibus acutis, approximatis; latere antico acuminato; latere siphonali latè rotundato, sub-truncato; margine dorsali recto; areâ dorsali planulata, lanceolatâ; margine ventrali leniter arcuato; area cardinalis ampla; fossâ ligamentali magnâ, dente V-formi parvo, classo, dentibus lateralibus compressis, quorum antico valvae dextrae bilobato; interior lactea; sinu siphonali angusto, elongato, spatulato. Long. 3 3/4; alt. 2 1/2; lat. 1 1/8 poll. (Gould.)

Remarks. — The specimen here provisionally identified as *Spisula falcata* is a small right valve 18 mm long and 11.6 mm high. The preservation is imperfect, but the very inequilateral outline and the remnant of the hinge agree well with juvenile specimens of *S. falcata.*

Reagan (Trans. Kansas Acad. Sci., Vol. 22, p. 204, 1909) reported "*Mactra (Spisula) falcata* Gould" from the Quillayute Formation in western Washington of Pliocene age and also from the "Purisima-San Diego" formation. This record from San Diego, however, is equivocal in that two formations from California are mentioned.

Spisula falcata brioniana Trask (1170) from the Briones Formation of late Miocene age, was described as differing from the typical species in the greater height in proportion to the length, more prominent umbonal ridge, shorter hinge plate and shorter distance from the center of the hinge plate to the distal ends of the lateral lamellae.

Spisula falcata bears a resemblance to *S. dolabriformis* Conrad (1171), which also is an elongated form, but may be separated from it by the character of the hinge. The right anterior accessory lamina extends toward and is separated from the lower lateral by only a slight gap whereas in *S. dolabriformis* the corresponding lamellae are offset and separated by a comparatively wide space. The same difference in the hinge also exists between *S. falcata* and *S. planulata* Conrad. The latter is much more equilateral and the shell is thicker.

Spisula (Mactromeris) hemphillii Dall
Plate 54, Figures 1-4, 9, Plate 57, Figure 16

Mactra hemphillii Dall, Nautilus, Vol. 7, No. 12, p. 137, pl. 5, fig. 2, April, 1894. "Distribution: San Diego, Hemphill and Cooper." Recent. — Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 204, 1909 (as *Mactra hemphilli).* Quillayte Formation, western Washington, Pliocene. Also "Purisima-San Diego."

Spisula hemphillii Dall, Packard, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 15, p. 287, pls. 21 and 22, May 1, 1916. Earlier records cited, Recent and Pleistocene. J. Q. Burch, Min. Conch. Club South. Calif., No. 44, p. 19, figs. (on p. 11 by T. A. Burch), February, 1945. "Redondo Beach, Calif. (Burch) to Corinto, Nicauragua [Nicaragua] (Eyerdam)" (1172).

Spisula hemphilli Dall, I. S. Oldroyd, Stanford Univ. Publ. Univ. Serv. Geol. Sci., Vol. 1, p. 194, pls. 46, 50 (reproduction of pls. 21, 22, by Packard, 1916), 1924. "Range San Pedro to San Diego, California, In the Pleistocene at San Pedro." — Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 83, 1929. "Pliocene of San Diego." Also "Purisima formation." — Fitch, State Calif., Dept. Fish Game, Mar. Fish. Branch, Fish Bull., No. 90, p. 88, fig. 54, 1953. "Range: Santa Barbara, California, to Ensenada, Baja California." — Abbott, American Seashells (D. Van Nostrand Co., Inc.: New York), p. 448, fig. 90b (p. 447), 1954. [Reproduction of Dall's (1894) illustration.]

Type specimen. — No. 15815, United States National Museum.

Type locality. — "San Diego," California.

Range. —? Late Miocene (Grant and Gale); Middle Pliocene to Recent. Recent, Monterey (1173) (rarely) Santa Barbara, California, to Todos Santos Bay, Lower California, Mexico, from intertidal zone (rarely) to 46 meters (25 fathoms); "in fine or firm, sandy mud in bays, sloughs and estuaries as well as more quiet protected areas along the outer coast" (Fitch).

Occurrence in San Diego Fm. — C.A.S. 1402, 28892. L.A.M. 107, 305, 305A, P.87, A-1323. S.D. 29, 331, 2939, 2946, 3592. U.C.L.A. 294, 312.

Original description.—Shell large, thin, inflated, subequilateral, creamy white with a yellow thin epidermis, which over the body of the shell in young shells is beautifully evenly concentrically striated and on the posterior dorsal area is irregularly wrinkled, with an elevated raphe of epidermis at the margin of the area; beaks rather prominent, the anterior end of the valves longer than the posterior; posterior dorsal slope excavated; lunule obscure, escutcheon marked by prominent elevated radial lines of epidermis; the dorsal margin pouting in front of the ligament, the posterior slope convex, the posterior flexure faint, but marked by a recession of the ventral border of the valves, which gape but very little and not at all in front; anterior end rounded, but smaller than the posterior; ventral border arcuate; hinge and pallial sinus much as in the last species [*Mactra catiliformis*] except that the sinus is somewhat smaller and less depressed. Lon. 120, alt. 93, diam. 50 mm. (Dall.)

Remarks. — Several well preserved specimens and many fragments of *Spisula hemphillii* from the San Diego Formation agree in all observable details with part of the type lot of that species. The largest specimen from Loc. 2946 (SD), from Reynard Way, San Diego, retaining most of the shell material, is 134.4 mm long, 102 mm high, convexity (both valves together) 48.8 mm. A specimen from Fossil Canyon east of Chula Vista [Loc. A1323 (LAM)], retaining patches of shell material, is 132.8 mm long, 104 mm high, convexity (both valves together), 58 mm. A smaller specimen, a right valve from Loc. 305 (LAM), near the Mexican boundary, is 114 mm long, 85 mm high, convexity 24 mm. Additional specimens from near the Mexican boundary in various states of preservation, are referable to this species.

A specimen from Loc. 28892 (CAS), from near the Mexican boundary, is 42 mm long, 31 mm high, convexity (both valves together), 17.4 mm. It agrees in all observable details with juvenile specimens in the original lot of *S. hemphillii.*

Five Recent specimens in the collections of the California Academy of Sciences, collected at San Diego by Henry Hemphill, apparently are part of the original lot upon which the species was based. The largest specimen is 133 mm long, 102 mm high, the convexity (both valves together) 51.3 mm. The pallial sinus extends forward 55 mm from the posterior end of the shell.

Grant and Gale (1931, p. 398) pointed out that there appears to be but little if any difference between the form described as *Spisula cameronis* Dall (1174), from beds of Pleistocene age at San Quintin, Lower California and *S. hemphillii.* It may be mentioned also that a decided similarity exists between two other species, *Spisula mossbeachensis* Glen (1175), a Pliocene species from the lower portion of the Merced Formation, and *S. longa* Dall (1176) from the Pleistocene at San Quintin. Judging from the illustrations, the form described as *Spisula (Mactromeris) hemphilli* var. *orcutti* Manager (1177) is a little higher in proportion to the length, the anterior end is a little broader and the pallial sinus is shorter, broader, and joins the pallial line at a greater angle than that of typical *S. hemphillii.*

The shell of *S. hemphillii* is decidedly higher in proportion to length in comparison to that of *S. dolabriformis* Conrad (1178), the type of *Simomactra* Dall, which was originally described from Panama. The same characters separate it from *S. strongi* T.A.Burch (1179), which at times has been confused with Conrad's species. Differences in the hinges of these three species also exist. The right valve of *S. strongi* has only three lateral teeth whereas that of *S. hemphillii* and *S. dolabriformis* each has four such teeth. The right lower anterior lateral of *S. dolabriformis* is not in line with the anterior arm of the cardinal whereas the corresponding lateral of *S. hemphillii* is separated from but in line with the lateral.

Woodring (1180) mentioned that the fossil form occurring in strata of a Pliocene age in the Santa Maria district which he cited under the name of "*Spisula* cf. *S. hemphilli* Dall" is identical with the form described by Arnold (1181) as *Spisula sisquocensis.* According to Arnold this form "is near *S. hemphilli* Dall, but is constantly and decidedly narrower."

Macrotoma revellei Durham (1182) described from beds of Pleistocene age on Coronado Island in the Gulf of California, resembles *S. hemphillii* in the general outline but the Gulf fossil is "more truncate posteriorly across the gape and less rostrate anteriorly." Furthermore, the pallial

sinus of *S. hemphillii* is considerably narrower and is directed gently upward whereas the pallial sinus on the fossil from the Gulf of California is wider and is directed slightly downward.

The shell of *S. hemphillii* is decidedly more elongated anteriorly than is that of *S. catilliformis* and the pallial sinus is inclined upward rather than downward as it is in Conrad's species.

Spisula (Mactromeris) mercedensis Packard
Plate 54, Figure 12

Spisula mercedensis Packard, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 15, p. 286, pl. 20 [not pl. 13 as cited], figs. 1a, 1b, May 1, 1916. — Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 110, 1944. Original record cited.

Spisula (Hemimactra) mercedensis Packard, Glen, Univ. Calif. Publ. Geol. Sci., Vol. 36, No. 2, p. 175, 1959. Loc. B-4804, "In cliff along Highway 1, approximately 4,000 feet north of Franciscan - Merced contact at Mussel Rock. Fossils collected at road level from massive, grey to brown, medium-grained sandstone with a few highly fossiliferous interbeds", type Merced, Pliocene.

Type specimen. — No. 11467, University of California Department of Paleontology.

Type locality. — "in the marine cliffs of the Merced group, near Mussel Rock, San Mateo County, California." "Pliocene: Merced group."

Range. — Middle Pliocene.

Occurrence in San Diego Fm. — L.A.M. 107.

Original description. — Shell large, ventricose, inequilateral, the beaks being considerably anterior to the middle of the shell; anterior dorsal edge short, slightly concave, with a faint suggestion of a lunule; posterior dorsal edge gently convex, curving regularly to the rounded extremity; anterior end evenly rounded; base broadly arcuate; umbones small, sharply pointed; an indistinct posterior flexure extends from the umbones to the base, much as in *Spisula catilliformis* Conrad. Surface roughened by numerous irregular lines of growth. Hinge plate wide, chond[r]ophore shallow, wide, overhung but slightly by the posterior arm of the cardinal; left cardinal large, arms of equal length, high; anterior lateral short, situated dorsal to the anterior arm of the cardinal; posterior lateral high and acutely pointed. Hinge of the right valve unknown. Pallial sinus not observed. The dimensions of the type are: length 124 mm , height 93 mm., convexity 32 mm. (Packard.)

Remarks.—One specimen of a large elongate *Spisula* in the collection from Loc. 107 (LAM) retains considerable shell material. The left valve is 136 mm long and 93 mm high. The convexity (both valves together but somewhat overlapping) is 58 mm. The beak is approximately 62 mm from the anterior end.

The elongate outline, indistinct posterior flexure, and anteriorly placed beaks are all characteristics of *S. mercedensis*. The hinge is not visible, but according to Packard the anterior lateral is separated from the anterior arm of the cardinal on the left valve.

This species is evidently closely related to *S. catilliformis* but the differences enumerated by Packard and those visible on the present specimen appear to justify recognition of this form as distinct from Conrad's species. This is the first record of *S. mercedensis* from strata other than those from the Merced Formation at the type locality and from southeast of Felt Lake in Santa Clara County.

Spisula (Mactromeris) cf. *S. (M.) planulata* Conrad
Plate 57 Figure 12

The following references, type locality, range and original description refer to typical *S. planulata.*

Mactra planulata Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 240, 1837.

Spisula falcata Gould, Packard, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 9, No. 15, pl. 26, figs. 1a, 1b, 1c, 1916. Recent.

Not *Mactra falcata* Gould, 1850.

Mactra (Spisula) planulata Conrad, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 397, 1931. Earlier records cited.

Spisula planulata Conrad, Morris, Field Guide to Shells of the Pacific Coast and Hawaii (Houghton Mifflin Co.: Boston), p. 56, pl. 15, fig. 6, 1952. Monterey, California, to Cape San Lucas, Mexico.

Type specimen. — Location unknown to present authors. [The type specimen could not be found in the Academy of Natural Sciences of Philadelphia, according to Dr. Robert Robertson (written comm., March 29, 1961).]

Type locality. — "Inhabits with the former" [that is, *Mactra californica* from "Inhabits muddy marshes, bare at low water, near Sta. Barbara; rare."]

Range. — Middle Pliocene to Recent. Recent from Monterey Bay, California, to Cape San Lucas, Lower California, Mexico (Dall), from intertidal zone to 91 meters (50 fathoms).

Occurrence in San Diego Fm. — L.A.M. 107. U.C.L.A. 294.

Original description. — Shell triangular, much compressed, subequilateral the posterior side rather shorter than the anterior; anterior side subcuneiform; posterior side with an obscure submarginal line, extremity rounded; beaks elevated; epidermis smooth, shining. Length, one inch and three-fourths. (Conrad.)

Remarks. — Two specimens in the present collections from near the Mexican boundary are provisionally referred to *Spisula planulata.* The largest one, the dorsal half of a right valve from Loc. 107 (LAM), is 74 mm long and 42 mm high. The beak is a little posterior to the middle of the valve. The lines of growth are comparable to the corresponding ones on Recent *S. planulata* of the same size. The other specimen is a small right valve, 30.8 mm long and 25 mm high, the ventral portion missing. It bears a decided resemblance to juvenile forms of *S. planulata* of the same size. The characters of the interior of these fossils is unknown and the identification is therefore not positive.

One of the largest Recent specimens of this species in the collection of the California Academy of Sciences, collected at San Diego by Henry Hemphill, is 68.8 mm

long, 50.6 mm high, convexity (both valves together) 25.2 mm the pallial sinus extends forward 30 mm from the posterior margin.

Spisula planulata has been confused with *S. falcata* Gould in the literature. It was not illustrated at the time of description by Conrad who stated that it was rare. The type specimen could not be found in the collections of the Academy of Natural Sciences at Philadelphia according to Dr. Robert Robertson of that institution. The results of a study of the literature and of specimens from various localities, especially from southern California, lead us to accept the interpretation of *S. planulata* given by Grant and Gale.

The shell of *S. planulata*, as recognized by us, is subtrigonal (although this character varies with juvenile forms) and the right anterior accessory lamella is rather steeply inclined and offset from the ventral lateral by a comparatively wide, flat area on the hinge plate.

The shell of *S. falcata* Gould, originally described from Puget Sound is thinner, decidedly more inequilateral and more attenuated anteriorly than *S. planulata*, and the right anterior accessory lamina on the hinge is nearly in line with and only slightly separated from the ventral lateral.

The shell of the generally more southern species, *Spisula dolabriformis* Conrad is more attenuated anteriorly than that of *S. planulata*, the anterior dorsal margin beneath the beak is more projecting, on the adult shells there is a narrow radial depression anterior to the posterior angulation, and the pallial sinus is wider.

Spisula planulata, *S. falcata*, and *S. dolabriformis* appear to be related species and have been discussed by Burch (1183) and by Hertlein and Strong (1184). Many of the records of the occurrence of *S. planulata* in beds earlier than Pleistocene in age need confirmation.

Another member of this group of species is *Spisula strongi* Burch (1185) which was described from Newport Bay, California. Through the courtesy of Dr. Harald A. Rehder we were able to examine the type specimen of that species. It is 52.2 mm long, 34.6 mm high, convexity (both valves together) 17.3 mm, and the pallial sinus extends forward 22.2 mm from the posterior end of the shell. The outline of the shell is similar to that of *S. dolabriformis* of the same size. The hinge of *S. strongi* differs from that species, as mentioned by Burch, in that it lacks what he designates as a proximal anterior lateral tooth adjacent to the cardinal teeth and there is but one anterior lateral on the right valve.

The shell of *S. planulata* is more highly trigonal in outline than that of *S. strongi*. Furthermore, a proximal anterior lateral tooth is present on the hinge of the left valve and there are two well developed laterals on the right valve.

GENUS *TRESUS* GRAY

Cryptodon Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, P. 235, 1837. Sole species: "*L. nutallii*" Conrad.

Not *Cryptodon* Turton, 1822, nor *Cryptodon* Latreille, 1833.

Tresus Gray, Ann. Mag. Nat. Hist., Ser. 2, Vol. 11, p. 42, January, 1853. Sole species: "*T. maximus.*" [Preceding the description of the genus, Gray mentions "*Lutraria* sp., Middend."] — Keen, Veliger, Vol. 4, No. 4, p. 179, 1962. "type species, by monotypy, *Lutraria maxima* Middendorff, 1849 [non Jonas, 1844] *L. nuttalli* Conrad, 1837" . . .

Not *Trésus* Walckenaer, Ann. Soc. Enotomol. de France, Tome 2, p. 438, October, 1833. Arachnida. [No species cited. A virtual *nomen nudum.*]

Schizothaerus Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 6, p. 199, January, 1853 [issued February 7, 1853, according to A. M. Keen]. Sole species: *Schizothaerus nuttallii* Conrad. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 404, 1931. Type: *Schizothaerus nuttallii* Conrad.

Type species (by monotypy). — *Tresus maximus* [Middendorff] [=*Lutraria maxima* Middendorff, Beiträge zu einer Malacozoologia Rossica (from Mém. Sci. Nat. Acad. Imper. Sci. St. Petersbourg, Ser. 6, Vol. 6), Pt. III, p. 66, pl. 19, figs. 1-4, 1849. "Fundort: Die Insel Sitcha (Wosness.)" Not *Lutraria maxima* Jonas, 1844].

Range. — Middle Miocene to Recent: Recent from Japan to Lower California, from the intertidal zone to 46 meters (25 fathoms).

Original description. — Shell ovate, oblong, ventricose, hinder gape roundish; cardinal teeth small, lateral teeth very small, close to the cardinal; siphonal inflection large, oblong. (Gray.)

Remarks. — The generic name *Tresus* Gray apparently was published about a month earlier than *Schizothaerus* Conrad, as mentioned by Dall in 1909. However, Dall retained usage of the name *Schizothaerus* because of *Trésus* Walckenaer, 1833. Keen (1962) presented evidence to justify the replacement of *Schizothaerus* by *Tresus* Gray and this procedure has been generally accepted by authors.

Trésus Walckenaer was published in a key in a classification of arachnids. In this key it appeared with *Myrmecia* [Walckenaer, 1836], *Platiscelum* [Audouin, 1826], and *Attus* [Walckenaer, 1805] and a brief statement, "Voltigeuses. Sautant et voltigeant avec agilitié pour attraper leur proie", applied to all four genera. *Trésus* is not mentioned elsewhere in the text and no species was assigned to it.

The usage of an accent mark does not indicate that name was used in a vernacular sense as believed by some workers. Such accent marks were used by others, for example, Gray (1186) mentioned "*Máctra grándis*", "*Spísula* elongàta" and others.

Keen considers *Trésus* of Walckenaer to be a *nomen nudum* and it may be so interpreted because the particular descriptive material in the key applies to four genera. However, it would be desirable that the Internat. Comm. on Zool. Nomencl. Rule on the taxonomic status of Walckenaer's genus.

In view of the questionable taxonomic validity of *Trésus* Walckenaer we use *Tresus* Gray in the present paper.

The name *Schizothaerus* (1187) was applied to this genus by Conrad "In allusion to the profound channel which idents the hinge of both sides of the cardinal teeth." The general shape of the shell of this genus, oblong and gaping, is probably the result of the burrowing habit of the animal.

Two and perhaps three species are known to occur

in late Tertiary beds in western North America and one or two in Kamtschatka and Japan. Two Recent species are usually recognized in the fauna of western North America and one or possibly two in Japan and the North Pacific.

Tresus nuttallii Conrad
Plate 54, Figure 11; Plate 55, Figures 9, 13, 14, 17

L[utraria]. Nuttallii Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 235, pl. 18, fig. 1, 1837. (Under subgenus *Cryptodon.)*

Schizothaerus nuttallii Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 6, p. 199, 1853. — Packard, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 15, p. 266 (in text), pl. 35, figs. 1a, 1b, 1916. Recent.—Packard, Univ. Calif. Publ. Zool., Vol. 14, No. 2, p. 283, pl. 28, figs. 1a, 1b, 1918. "Kodiak Island to Todos Santos Bay, Lower California."—I.S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 60, pl. 33, figs. 1a, 1b, 1924. "Wrangell, Alaska, to San Diego, Calif." Recent. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 196, pl. 31, figs. 1a, 1b, 1924. "Wrangell, Alaska, to San Diego, California. In the Pleistocene at Santa Barbara and San Diego, and the Pliocene at Santa Barbara, California." —Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 404, pl. 22, fig. 9; pl. 23, figs. 8a, 8b, 9, 1931. Late Miocene to Recent.— J.Q.Burch, Min. Conch. Club South. Calif., No. 44, p. 22, five figs. (on pp. 23-24), 1944. "Bolinas, Calif. to Scammon's Lagoon, Lower Calif." Recent.—Swan and Finucane, Nautilus, Vol. 66, No. 1, pp. 19-25, pl. 2, 1952. "extends at least as far north as 48°N." (p.23).— Fitch, State Calif. Dept. Fish Game, Mar. Fish Branch, Fish Bull. No. 90, p. 89, fig. 55, 1953. "Range: Puget Sound to Scammons Lagoon, Baja California," Recent.

Tresus nuttalli Conrad, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 70, pls. 33, 34, 1968. San Diego region, Pleistocene. Also Miocene to Recent in California.

Type specimen. — Holotype No. 61.5.30.134, British Museum (Natural History) (A. M. Keen, Veliger, Vol. 8, No. 3, p. 170, 1966).

Type locality. — "Inhabits salt marshes, bare at low water, in the vicinity of Sta. Barbara." [California.]

Range. — Late Miocene (Briones Formation) to Recent. Recent, Wrangell, Alaska (Dall), to Scammon's Lagoon, Lower California, Mexico; in bays, estuaries, esteros and sheltered areas on the outer coast, from high tide line to 46 meters (25 fathoms).

Occurrence in the San Diego Fm. — C.A.S. Loc. 1402. L.A.M. Loc. 107, 305, 305A, 309. S.D. Loc. 408, 417. U.C.L.A. Loc. 1383, 2420.

Original description. — Shell elliptical, slightly gibbous from beak to base; posterior side produced; ligament margin slightly declining, rectilinear, extremity obliquely subtruncated; umbo prominent; colour white; epidermis very thin, brown, wrinkled on the margins. Length, six inches. (Conrad.)

Remarks. — *Tresus nuttallii* is represented in the collections from the San Diego Formation by a number of specimens, mostly single valves and hinges in various states of preservation. The largest specimen is a left valve from Loc. 305 (LAM), near the Mexican Boundary. It is 150 mm long (posterior end incomplete) and approximately 112 mm high. A smaller specimen, both valves, from Loc. 2420 (UCLA), from Pacific Beach is 110.6 mm long, 74.6 mm high, convexity (both valves together, separated by about 3 mm) 51 mm. All the shell characters of these fossils are similar to those of Recent specimens from adjacent waters.

A large Recent specimen from Loc. 4649 (CAS), collected at San Diego, is 162 mm long, 98 mm high, convexity (both valves together) 71.5 mm; the pallial sinus extends forward and gently downward 94 mm from the posterior end of the shell. A huge Recent shell (1188) from Vaughan Bay, Washington, was reported to be 206 mm long and 139 mm high. This species also occurs elsewhere in Pliocene strata at various localities in California.

The shell of *Tresus nuttallii* is larger, longer, more ventricose, the anterior end is longer and the posterior gape is more rounded than that of *Tresus pajaroanus* Conrad (1189), a Pliocene species originally described from strata now considered to be referable to the Purisima Formation.

Three names for Recent West American species referable to *Tresus* were proposed subsequent to the description of *T. nuttallii. Lutraria maxima* Middendorff 1849 (1190), (not *Lutraria maxima* Jonas 1844), (1191), from Sitka, Alaska, is referable to *Lutraria capax* Gould 1850, (1192) from Puget Sound and *Lutraria inflata* Dunker 1853, (1193) described from California, believed to be a synonym of *T. nuttallii.*

Swan and Finucane (1194), made a careful study of *Tresus nuttallii*, also the rounded form, *T. capax*, which they considered to be a distinct species. They concluded that the adults of the rounded northern form are usually readily separable from *nuttallii*, that it usually burrows less deeply in more compact mud and gravel mixtures, that it withstands lower temperature, and that there are differences in the details of the animals of the two species. More recently Pearce (1195) also presented evidence to indicate that the two are separate species. Pholo (1196) described the changes of form and mode of life of *T. nuttallii.*

The name *Schizothaerus nuttallii bighopensis* was proposed by Henderson (1197) for a fossil form of Pleistocene age, from Big Hope Island in Puget Sound. This form, according to Henderson, differs from the rounded form described as *Lutraria capax* by Gould in "being invariably thick, very coarse and rough, proportionately higher and the beaks more nearly central than in any recent material I have seen from there or elsewhere."

A species occurring in Japanese waters, often referred to *Schizothaerus nuttallii* was later described as *Schizothaerus keenae* by Kuroda and Habe (1198). The shell of the Japanese species is higher and the posterior truncation is broader than that of *T. nuttallii.* An extensive discussion of the habitat of this clam was published by Cahn (1199). A Miocene fossil in Japan, *Schizothaerus nuttallii kissyuensis* Hatai (1200), was described prior to *S. keenae* and the latter needs comparison with the fossil form.

ORDER ASTHENODONTIDA DALL
SUPERFAMILY MYACEA GOLDFUSS
FAMILY MYIDAE GOLDFUSS (1201)

Burrowers in sand or mud, sometimes nestlers, usually with elongated or ovate, subequal valves but often irregular or distorted in nestling forms, the surface white, earthly or chalky, often with coarse concentric growth sculpture and a covering periostracum. Ligament mostly internal; in the left valve, the resilium is attached to a large projecting arm or chondrophoral plate, the resilifer being a rounded or sagittate scar bordered above and behind by a small ridge (nymph); this chondrophoral arm fits into a deep pit in the beak of the right valve, the scar of the resilifer is placed in the roof of the umbone within, while above it on the posterior margin of the within, while above it on the posterior margin of the valve, there is a smaller scar to which the external portion of the ligament (tensilium) is attached. Hinge margin with or without teeth. Internal margins of valve smooth. Pallial sinus present or wanting. (Olsson, Mollusks of the Tropical Eastern Pacific. (Paleo. Res. Inst.: Ithaca, New York), p. 422, 1961.) Paleocene to Recent.

Remarks. — Four genera of the family Myidae are represented in the Pliocene of California, two of which occur in the San Diego Formation. In general, the members of this family live in shallow (low water to 50 meters, rarely to 265 meters), boreal and temperate waters where they burrow in muddy bottoms or nestle in cavities. Lamy (1203) published a revision of the members of this family represented in the collection of the Natural History Museum in Paris.

The genus *Mya* has not been reported from the San Diego Formation but it is represented from Miocene to Recent in strata along the northeastern Pacific. A subgenus *Antiguamya* Effinger (1204) was described from the Gries Ranch beds of early Oligocene age in western Washington.

A paper by Fujie (1205) contains an account of the genus *Mya* and its species in Japan. More recently, a paper by MacNeil (1206) contains a thorough discussion of the evolution and distribution of *Mya*.

Key to Genera of Myidae

A. Pallial sinus large and broadly rounded . . . . . *Sphenia*

B. Pallial sinus very short or lacking . . . . . *Cryptomya*

GENUS *CRYPTOMYA* CONRAD

Cryptomya Conrad, Proc. Acad, Nat. Sci. Philadelphia, Vol. 4, p. 121, December, 1848. Sole species, *Sphaenia californica* Conrad. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 416, 1931. Type (by monotypy): *Sphaenia californica* Conrad. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 423, 1961. Type by monotypy.

Type species (by monotypy). — *Sphaenia californica* Conrad.

Range. — Late Oligocene (San Ramon) or early Miocene, to Recent. Recent from the littoral zone to 91 meters (50 fathoms).

Description. — Shell small, ovate, slightly gaping posteriorly; similar to a small *Mya* from which it differs in that the pallial sinus is very short or lacking; chondrophore similar to that of *Mya arenaria*.

Remarks. — The shells of the species of this genus are somewhat variable in shape and this variability has led to the description of a number of species based upon rather slight differences.

Lamy (1207) discussed the Recent species of this genus in the collections of the National Museum of Natural History in Paris. Beets (1208) in 1950 cited ten species occurring as fossils, with the range of the genus from Miocene to Recent. There may be additional species, for his list lacks references to two fossil forms described in western North America, *Cryptomya incognita* Clark, from the San Ramon Formation, referred to late Oligocene age, and *C. quadrata vancouverensis* Clark and Arnold from the Sooke Formation, of late Oligocene or early Miocene age. In Japan and the East Indies this genus is known to occur from Miocene to Recent. Recent species have been reported from west Mexico to the East Indies and one species from the Red Sea and Australia. *Venatomya* Iredale (1209) was proposed as a genus with the Australian species, "type *Sphaenia elliptica* A. Adams."

Key to Species and Subspecies of *Cryptomya*

A. Maximum length about 37 mm; umbos usually gently inflated . . . . *californica*

B. Maximum length about 48 mm; umbos usually moderately inflated . . . . . (subspecies) *magna*

Cryptomya californica Conrad
Plate 55, Figures 3, 4, 7, 16

S[phaenia]. californica Conrad, Jour. Acad. Nat. Sci. Philadelphia Vol. 7, Pt. 2, p. 234, pl. 17, fig. 11, 1837.

Cryptomya californica Conrad, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 296, 1874. "Well at San Diego." "Pliocene.—Dall. Proc. U.S. Nat. Mus., Vol. 1, p. 28, 1878. Well at San Diego.—Cooper, Calif. State Min. Bur., Seventh Ann. Rept. State Mineral., p. 237, 1888. "Pl. — . . . San Diego well." — Orcutt, West Amer. Sci., Vol. 6, whole No. 46, p. 85, August 1889. Dall's record (1874) cited. — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 180, 1903. Cooper's record (1888) cited. — Orcutt, cited by Ellis in Ellis and Lee, U.S.G.S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 48. Dall's record (1874) cited.—Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 423,

pl. 77, figs. 2, 2a, 1961. Alaska to Bayovar, Peru.
Mya (Cryptoma) californica Conrad, Packard, Univ. Calif. Publ. Zool., Vol. 14 No. 2, p. 284, pl. 31, figs. 2a, 2b; pl. 53 (chart, distribution), 1918. Numerous localities in and near San Francisco Bay, California. "Range. — Chichagoff Island, Alaska to Topolobampo, Mexico (Dall)."

Type specimen. — Location unknown to the present authors.

Type locality. — "Inhabits salt marches, near Sta. Barbara; rare."

Range. — Late Miocene (Briones Formation) to Recent. Recent from Chichagoff Island, Alaska, to Bayovar, Peru. Along the beach in a zone just below *Heterodonax bimaculatus* Linnaeus (J.Q. Burch) (1210).

Occurrence in San Diego Fm. — San Diego well (Dall). L.A.M. Loc. 305.

Original description. — Shell suboval, convex-depressed, with radiating striae; obscure, except towards the posterior extremity, where they are distinct; posterior margin obliquely truncated, rectilinear; beaks central, ligament margin arcuate; tooth much dilated, oblique; colour white, palleal impression without a sinus, but forming a right angle posteriorly. (Conrad.)

Remarks. — *Cryptomya californica* was reported from the San Diego well by Dall in 1874. Apparently the later published records of the occurrence of this species in the San Diego Formation are based on that of Dall.

A number of valves here referred to *C. californica*, most of them fragmental, were collected by G. P. Kanakoff near the Mexican boundary. The largest one is a right valve, 16.2 mm long, and 13.3 mm high. Several valves are rather highly convex, probably as a result of the habitat.

Several small casts in the collections of the San Diego Society of Natural History lacking information as to the locality from which they came, might be referable to this species, but their small size and imperfect preservation are such that it is uncertain whether they should be referred to this species or to the subspecies *C. californica magna.*

The shell of this species is variable in outline and several other species described from the late Tertiary of western North America may be identical or at most subspecies of *Cryptomya californica.* A Recent specimen of average size from San Diego, collected by Frank Kelsey, is 31.8 mm long, 23 mm high, convexity (both valves together). 12.6 mm. A very large, somewhat quadrate specimen collected by Henry Hemphill at Tomales Bay, California, is 37 mm long, 29 mm high, convexity (both valves together) 15 mm. Grant and Gale placed six taxa in the synonymy of this species but we consider at least one of these, *C. magna*, to be a separate subspecies.

Cryptomya incognita Clark (1211) from the San Ramon Formation in Contra Costa Co., California appears to be a relative of *C. californica* but it is smaller and the chondrophore is said to differ in that there are two ridges bounding the resilium pit posteriorly rather than one.

Two other species of *Cryptomya* have been described from beds of Pliocene age in California and Oregon. *Cryptomya quadrata* Arnold (1212) was described as differing from *C. californica* by the more rectangularly truncated posterior end, less sloping dorsal margins and in the greater size. *Cryptomya oregonensis* Dall (1213) was described as differing from *C. californica* by its subrhombic shape. Some authors have placed the Oregon species in the synonymy of *C. californica* but more recently Weaver (1214) treated it as a valid species.

Cryptomya californica occurs at the present time along western North America in shallow water both in sheltered bays and along the open coast. MacGintie (1215) mentioned that it may inhabit burrows of certain species of crabs to a depth of 51 cm (20 inches). J.Q. Burch mentioned that empty shells were dredged to depths of 18, 27, and 91 meters (10, 15, and 50 fathoms), and Yonge discussed the structure and adaptations of this species (Univ. Calif. Publ. Zool., Vol. 55, No. 6, pp. 395-400, figs. 1-4, 1951).

This species has been reported living in Japan but according to Habe (1216) the oriental species is referable to *Cryptomya busoensis* Yokoyama.

Cryptomya californica magna Dall
Plate 54, Figures 10, 13;
Plate 55, Figures 8, 10, 12

Cryptomya magna Dall, West Amer. Sci., Vol. 19, No. 2, p. 17, April 27, 1921.—Dall, Proc. U.S. Nat. Mus., Vol. 66, Art. 17, No. 2554, p. 15, pl. 13, figs. 3, 4, September 22, 1925. "Pliocene (?) of San Quintin Bay, Lower California." — Manager, Johns Hopkins Univ. Stud. Geol., No. 11, p. 293, 1934. San Quintin Bay, Lower California, Pleistocene.

Type specimen.—No. 333127, United States National Museum.

Type locality. — "San Quintin Bay, Lower California . . . . late Pliocene or early Pleistocene . . . . ."

Range. — Middle Pliocene (San Diego Formation); Pleistocene (San Quintin Bay), Lower California, Mexico.

Occurrence in San Diego Fm. — C.A.S. Loc. 1402. L.A.M. Loc. 305, 305A, 319. S.D. Loc. 29. U.C.L.A. Loc. 312, (cf) 1386.

Original description. — Shell oval, inflated, thin, nearly equilateral and equivalve, sculptured only with rather prominent incremental lines; beaks low, nearly central, posterior end very slightly more attenuated than the anterior end; hinge with a very large receptacle for the ligament with a strong ridge at the anterior and posterior edges; a small anterior lateral in the left valve, right valve edentulous; posterior muscular scars larger than the anterior; pallial sinus almost obsolete. Length 35; height 24; diameter 17 mm. (Dall.)

Remarks. — Several well preserved specimens from Balboa Park in San Diego agree in shape and size with the form described by Dall as *Cryptomya magna.* The only feature mentioned in his original description which we have not observed on the present fossils is an anterior lateral tooth on the left valve. However, this is not shown on his illustration of the type. We have examined specimens of a *Cryptomya* from the type locality and we have not observed any distinct anterior lateral on any of the left valves.

The present fossils from the San Diego Formation are much larger and more elongate than Recent specimens of *Cryptomya californica.* The largest specimen we have ob-

served is a right valve from Loc. 29 (SD), Balboa Park, San Diego, 48 mm long, 35.8 mm high (incomplete), convexity (one valve) 9.4 mm. Nearly all the specimens from Balboa Park attain a length between 40 and 45 mm. The size and shape of these fossils differ from those of Recent *Cryptomya californica* sufficiently to justify subspecific status for Dall's *Cryptomya magna.*

One cast from Reynard Way in the collections of the San Diego Society of Natural History appears to be referable to this subspecies. Several small casts in the collections of the same institution which lack information as to the locality from which they came may perhaps be referable to this form.

This is the first record of the occurrence of this large subspecies from a locality other than the type locality in beds of Pleistocene age at San Quintín Bay, Lower California.

GENUS *SPHENIA* TURTON

Sphenia Turton, Conchyl. Insul. Britannicum, pp. XVII, 36, 1822. Species cited, *Sphenia binghami* [Turton], *S. swainsoni* Turton, *S. decussata* [Montagu]. — Cossmann and Peyrot, Act. Soc. Linn. Bordeaux, Tome 63 (Conch. Néog. L'Aquitaine, Tome 1), p. 87, 1909. "G. - T.: *S. Binghami* Turton." — Lamy, Jour. de Conchyl., Vol. 70, No. 3, p. 176, 1927. "dont le type est *S. binghami* Turt." — Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 149, 1953. "Type by subsequent designation, Gray, 1847: *S. binghami* Turton."

"*Spaena* Turton" and "*Sphaenia* Turton" of authors.

Type species (by subsequent designation, Gray, Proc. Zool. Soc. London for 1847, p. 190). — "*Sp. Binghami*" [Turton, Conchyl. Insul Brit., p. 361, pl. 3, figs. 4, 4; pl. 19, figs. 3, 1822. "Rocks in Torbay." Also illustrated by H. and A. Adams, Gen. Rec. Moll., Vol. 2, p. 357, 1856, pl. 95, figs. 4, 4a, 4b, 1855. — Tryon, Struct. and Syst. Conch., Vol. 3, pl. 105, fig. 96, 1884. Europe.— Lamy, Jour. de Conchyl., Vol. 70, No. 3, p. 178, two figs. (p. 176), 1927. For a discussion of this species see Yonge, C. M., "Observations on *Sphenia binghami,*" Jour. Mar. Biol. Assoc. U.K., Vol. 30, No. 3, pp. 387-392, 2 figs. in text, 1951.]

Range. — Paleocene to Recent. Recent, widespread, from intertidal zone to 393 meters (215 fathoms), most abundant in cool and temperate waters.

Description. — Shell generally small, inequivalve, elongate, usually irregular because of a nestling habit. External surface marked only with irregular growth-lines sometimes divided into resting stages. Hinge teeth absent. Left valve with an elongate, flattened chondrophore which extends or fits obliquely under the umbonal margin of the right valve. Pallial sinus large and broadly rounded. (Olsson and Harbison.)

Remarks. — Three species attributed to this genus (one doubtfully) have been reported from strata of Tertiary age in California. Five species are reported to be living in waters between Alaska and San Diego, California, and at least three species have been described from tropical west American waters.

The genus *Sphenia* is reported here for the first time from the San Diego Formation. One species, *Sphenia* cf. *S. globula* Dall was reported by Woodring from the Foxen Mudstone of Pliocene age in the Santa Maria district in Santa Barbara Co.

E. A. Smith (1217) discussed the genus *Sphenia* in which he included ten Recent species. Lamy, 1927, also discussed this group of pelecypods.

Sphenia cf. *S. luticola* Valenciennes
Plate 56, Figures 21, 22

The following are references to typical *S. luticola.*

Corbula luticola Valenciennes, Zool. Voy. Venus, Atlas, Moll., pl. 24, figs. 6, 6a, 1846 [No locality cited.]

Sphaenia fragilis Carpenter, Cat. Mazatlan Shells Brit. Mus., p. 24, August, 1855. — Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 543, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, p. 29, 1872.—Brann, Illustrations to "Catalogue of the Collection of Mazatlan Shells" by Philip P. Carpenter (Paleo. Rest. Inst.: Ithaca, New York), p. 12, pl. 5, fig. 35; pl. 6, fig. 35, 1966. — Keen, Veliger, Vol. 10, No. 4, p. 400, text fig. 22, 1968.

Sphenia fragilis Carpenter, de Folin, Les Méléagrinicoles (Havre), p. 15, pl. 2, figs. 7, 9, 1867. — E. A. Smith Ann. Mag. Nat. Hist., Ser. 6, Vol. 12, p. 279, pl. 15A, figs. 4, 5, 1893. "Hab. Mazatlan, west coast of Mexico."— Lamy, Jour. de Conchyl., Vol. 70, No. 3, p. 179, 1927. "Californie."—K.V.W. Palmer, Geol. Soc. Ame., Mem. 76, p. 116, 1958. Earlier records of range cited. — Franc, Traité de Zool., Vol. 5, Fasc. 2, p. 2150, fig. 1801 E (p. 2121), 1960. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 424, pl. 77, figs. 9, 9a, 9b, 1961. "Venado Beach, Panama Canal Zone." Range: "Oregon ? to Northern Peru."

Type specimen of *Corbula luticola.* — Muséum Nationale d'Histoire Naturelle, Paris. Type material of *Sphenia fragilis* is also in the British Museum (Natural History) (see Lamy, 1927, p. 180).

Type locality. — No locality originally cited for *Corbula luticola.* Of *Sphenia fragilis,* "Hab. — Mazatlan: inhabiting the burrows of worms and Mollusks in Chamae and *Spondylus Lamarckii;* also in dead Balani on *Strombus galea;* not uncommon; L'pool & Havre coll."

Range. — Oregon?; California to Zorritos, Peru.

Occurrence in San Diego Fm. — L.A.M. Loc. 305.

Original description of *Sphenia fragilis.* — S. animali in cryptis latibulante, ergo ovarie distorto; testâ parvâ, tenui, subnacreâ, vix rugose striatâ; epidermide fuscovirente copiose indutâ, regarum increscentium concentricarum plenâ, postice in siphone longâ porrectâ: parte posticâ plus minusva subcarinatâ; valvâ sinistrâ dente ligamentum ferente, plus minusve seu prolongatâ seu extanta; dextra alveo conveniente, nonnunquam denticulo subextante: impressionibus muscularibus subrotundatis, sinu palii lato, rotundato, haud alto. (Carpenter.)

Largest specimen, Long. .18, Lat. .31, alt. .14 inches (Carpenter).

Remarks. — One left valve of a *Sphenia* about 4 mm long, was collected by George P. Kanakoff at Loc. 305 (LAM) near the Mexican boundary. A study of this

specimen leads us to refer it provisionally to *Sphenia luticola.*

Carpenter in 1864 mentioned that his "*Sphaenia fragilis* is perhaps *S. luticola,* Val." Lamy, in 1927, stated that an examination of two "specimens-types" of *Corbula luticola* Valenciennes, 1846, confirmed Carpenter's suggestion that *S. fragilis* is identical with the species described by Valenciennes.

Sphenia pacificensis de Folin (1218) is believed by Keen (1219) to be only a more elongate form of *S. fragilis* from Panama.

Olsson (1961, p. 423) mentioned that specimens in the U. S. National Museum from Oregon and California which are labelled *Sphenia fragilis* are much larger than specimens of *S. fragilis* from the Panamic region. He suggested that the northern shells may be referable to *S. trunculus* Dall (1220) which is probably only a large form of *S. fragilis.*

SUPERFAMILY CORBULACEA BOWDICH (1221)
FAMILY CORBULIDAE BOWDICH (1222)

The shell is small or medium size, rarely large, elongately ovate, usually solid, the beaks generally submedian, the anterior side rounded, the posterior side rostrated and pointed at the end. The right valve is usually larger and with stronger sculpture, the left valve may be similar, or much smaller, with a more rounded outline, its surface flat or depressed, and with finer or smoother sculpture. The ligament is entirely internal, attached to an armlike resilifer in the left valve, simulating a large tooth, which fits into a deep socket-like resilifer in the right valve. Hinge armature is variable but most Corbulas have a single, large, hooked cardinal tooth in the right valve placed in front of the resilial pit; there is a single cardinal socket in the left valve; lateral teeth are absent in most groups. The pallial line is entire or it may carry a small obscure posterior sinus. Surface covered with a periostracum, sometimes heavy. [Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 426, 1961.] Triassic to Recent.

Remarks. — A number of genera and subgenera of this family have been described. A satisfactory assignment of some of the species to the known supraspecific units often offers difficulties.

Papers by Gardner (1223) and by Vokes (1224) are an aid to anyone dealing with the Corbulidae. A catalogue of the Recent species in the collections of the Natural History Museum in Paris was published by Lamy (1225).

GENUS *CORBULA* BRUGUIÈRE

[*Corbula* Bruguière, Tabl. Encyclop. Méth. Vers Test.,Vol. 2, pl. 230, 1797. [Illustrations with genus name only, no text or specific names.] — Lamarck, Syst. Anim. s. Vert., p. 137, 1801. Species cited: *Corbula sulcata, C. laevigata, C. margaritacea, C. gallica, C. striata.* — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 286, 1930. Type species as designated by Schmidt, 1818, *Corbula sulcata* Lamarck.—Vokes, Bull. Amer. Mus. Nat. Hist., Vol. 86, Art. 1, p. 7, 1945. Type designated by Schmidt, 1818.—Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 145, 1953. Type designated by Schmidt, 1818.

Not *Corbula* Röding in Bolten, Mus. Bolt., p. 184, 1798. [= *Asaphis* Modeer, 1793.]

Aloidis Megerle von Mühlfeld, Ge. Naturfor. Freunde zu Berlin, Vol. 5, p. 67, 1811. Species cited: *Aloidis guineensis.* Ref. to "Linn. Syst. Nat. pag. 3287" and "Chemn. Conch. 10.t.172.f.1670. 1671." — Hertlein and Strong, Zoologica, Vol. 35, Pt. 4, p. 236, 1950. "Type (by monotypy): *Aloidis guineensis* Megerle von Mühlfeld." [= *Corbula sulcata* Lamarck.]

Type species (designated by Schmidt, Versuch Conch.-Samml., p. 77, 1818): — "Typ. *Corbula sulcata.* Encyclop. tab. 230. Fig. 1. a. b. c." [Lamarck, Syst. Anim. s. Vert., p. 137, 1801. No locality cited. — Lamarck, Hist. Nat. Anim. s. Vert., Vol. 5, p. 495, 1818. "Habite. . . .l'Océan indien?" — Illustrated by Reeve, Conch. Icon., Vol. 2, *Corbula,* sp. 2, pl. 1, fig. 2, 1843. "Hab. Senegal." — Vokes, 1945, p. 7 et seq., pl. 1, figs. 1-5. Senegal, Recent.]

Range. — Triassic?; Jurassic to Recent. Recent from the intertidal zone to 2699 meters (1476 fathoms).

Description. — Shell inequilateral, inequivalve, the right valve somewhat larger than the left, which it clasps or overlaps along the ventral margin, solid, rostrated. Right valve has a large anterior cardinal tooth in front of a deep resilial pit and a smaller posterior lateral tooth. Left valve carries a heavy hinge plate bearing a large, deep cardinal socket, a smaller pit for the resilium behind it (not a separate chondrophore plate), a rather large, knoblike posterior cardinal, and a small posterior lateral socket. Sculpture of both valves of strong concentric riblets. Both valves have a prominent umbo ending in an incurved beak, narrowly rostrated or pointed behind, the rostral area forming a depressed or concave escutcheon-like zone, bounded externally by an angle or keel running from the beak to the posterior extremity of the shell. (Olsson and Harbison.)

Remarks. — The use here of the genus name *Corbula* is based upon the ruling of the Internat. Comm. Zool. Nomencl. in 1950. In that ruling (1226) it was stated that a genus name appearing on a plate but without explanatory matter is to be considered as published if it appeared prior to January, 1931. This is not a very satisfactory solution because it leaves open to personal opinion the identification of the species represented by unidentified figures. The ruling, however, appears to be clearly applicable to the name *Corbula.* If for any reason the name *Corbula* should be abandoned, *Aloidis* Megerle von Mühfeld would take its place.

Eames (1227) discussed the genus *Corbula* and considered Gray's (1228) designation of *Corbula sulcata* to be the first valid designation of type species of this genus rather than that of Schmidt because the type designation by the latter refers to *Corbula* of Lamarck. However, most authors accept Schmidt's earlier designation of the same species as the type of *Corbula.*

There are between 75 to 100 Recent species which have been assigned to *Corbula* or to subgenera allied to it. These live in sand or mud in warm, often shallow waters along the seashore or in estuaries although species have

been reported from depths exceeding 2000 meters. Most of the species do not exceed 10 mm in length but some attain a length of 30 mm or more.

SUBGENUS *VARICORBULA* GRANT AND GALE

Varicorbula Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, pp. 12, 420, November 3, 1931.—Vokes, Bull. Amer. Mus. Nat. Hist., Vol. 86, Art. 1, p. 12, 1945. Type designation by Grant and Gale cited.—Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 147, 1953. "Type by original designation: *Corbula gibba* (Olivi)."—Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 438, 1961. Type as in preceding reference.

Type species (by original designation). — "In case a new name is needed for the *gibba* group, we propose *Varicorbula*, with *Corbula gibba* (Olivi) as figured by Bucquoy, Dautzenberg and Dollfus for the type." [See Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. du Roussillon, Tome 2, Fasc. 11 (Pelecypoda, Fasc. 24), p. 578, pl. 85, figs. 1-6 (typical), 7-23 (varieties), 1896. Mediterranean, Adriatic, Sea of Marmora; Atlantic Ocean from Norway to the Canary Islands, Also Miocene to Recent.—Vokes, 1945, p. 8, pl. 1, figs. 11-15. "Recent. Zetland, British Isles."—Tebble, British Bivalve Seashells [British Museum (Nat. Hist.)], p. 171, text fig. 91a, b, c, 1966.]

Range.—Late Cretaceous (Maestrichtian) to Recent. Recent from the intertidal zone to 2697 meters (1476 fathoms).

Description. — Shell small or of medium size, subrounded and with strongly discrepant valves as to size and sculpture. Right valve larger, higher, more convex, obtusely rostrated and slightly produced posteriorly, generally sculptured with strong, concentric riblets. Left valve smaller, flatter, subelliptical in form, its surface smoother, and bearing a few irregularly distributed radial threadlets on its ventral portion. Hinge: right valve, as in other Corbulas, has a single large cardinal tooth in front of a deep resilial pit; left valve with a small projecting chondrophore, its inner portion carrying a resilial scar, bounded behind by an elevated lamella which may function as a substitute tooth, and which fits into a small depression along the posterior side of the resilial pit of the opposite valve. (Olsson and Harbison.)

Remarks. — The shell of *Varicorbula* differs from that of typical *Corbula* in the very fine sculpture on the left valve which also often bears some irregularly spaced radial threads on the ventral portion. Also the left valve has a small, projecting chondrophore, a feature lacking on the type species of *Corbula*.

Vokes, 1945, gave *Varicorbula* generic status and placed it in a new subfamily, Caryocorbulinae, and this was followed later by several authors. We follow the more conservative course by treating it as a subgenus of *Corbula*, at least until the systematics of the family Corbulidae is more stabilized.

The similarity of *Varicorbula* to *Notocorbula* Iredale (1229) was mentioned by Woodring (1230) and later by Eames both of whom suggested possible relegation of it to the synonymy of Iredale's genus. The type species of *Notocorbula* has a well developed rostrum posteriorly and the cardinal tooth was described as keeled. Vokes accepted *Notocorbula* as a valid genus but did not suggest any close relationship to *Varicorbula*.

Yonge (1231) discussed the habits and adaptations of the European species *Corbula gibba*, the type of *Varicorbula*. The development of sculpture of inequivalve mollusks, including *Corbula* was discussed by McLean (1232).

Corbula (Varicorbula) gibbiformis Grant and Gale
Plate 57, Figures 3, 4

Corbula (Corbula) gibbiformis Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 420, pl. 19, figs. 4, 5, 6, November 3, 1931.

Corbula (Varicorbula) gibbiformis Grant and Gale, Woodring, U. S. G. S., Prof. Paper 190, p. 55, pl. 6, figs. 8, 9, 1938. "Great American Petroleum Co. Tuffree No. 2, East Coyote field, depth 3,351 to 3,356 feet; U. S. G. S. locality 13873." — Woodring, et al., in Winterer and Durham, U. S. G. S., Prof. Paper 334-H, p. 304, 1962. Pico Formation, north and south side of Santa Clara River Valley.

Corbula gibbiformis Grant and Gale, Vedder, U. S. G. S., Prof. Paper 400-B, p. B327, 1960. "Niguel formation," also "Eastern Ventura basin."

Type specimen. — No. 172, San Diego Society of Natural History.

Type locality. — "Southern California Gas Company's well No. 1-4, Sec. 4, T. 28 S., R. 23 E., Kern County, depth 3951-2 feet, upper Etchegoin formation, upper Pliocene."

Range. — Middle Pliocene.

Occurrence in San Diego Fm. — U.C.L.A. Loc. 2359.

Original description. — Shell of medium size, trigonal, plump; right valve strongly ventricose, with strong, concentric, closely-spaced riblets, left valve smaller, more elongate, with about five low, narrow, sharp radial riblets; right hinge with one strong cardinal tooth beneath the curved-over umbo and anterior to a prominent pit; left valve with a pit and a low, tooth-like prominence posterior to it. Length, about 13 mm.; height, about 13 mm. (Grant and Gale.)

Remarks. — Six specimens, mostly small, are present in the collection from Loc. 2359 (UCLA). The largest specimen, a right valve, is 14.9 mm long, 14.6 mm high, convexity, 7.3 mm. All of these specimens have lost some of the outer layer of the shell as a result of erosion. Concentric sculpture is visible on some portions of larger specimens and faint radial sculpture is visible on some of the left valves. The hinge of the right valve bears a small tooth similar to that shown in the figure of the paratype (fig. 4) by Grant and Gale. The fossils from the San Diego Formation appear quite similar to the illustrations of *C. gibbiformis* published by Woodring. The state of preservation of the specimens is imperfect but their close resemblance to *C. gibbiformis* leads us to refer them to that species. Specimens comparable to *C. gibbiformis* were recorded by Stewart (1233) from the *Pecten* zone of the

San Joaquin Formation in the San Joaquin Valley.

Corbula gibbiformis bears considerable resemblance to *C. speciosa* Reeve (1234), a tropical west American species, but the Pliocene species apparently has more regular, finer, concentric sculpture and a smaller tooth in the hinge of the right valve. Furthermore, the fossils lack the subquadrate shell development (nepioconch) which forms the umbo of the right valve of *C. speciosa* for a distance of about 5 mm and then changes abruptly to coarse rugose concentric sculpture. This early shell development on *C. speciosa* has much the appearance of *C. marmorata* Hinds.

Corbula nuciformis Sowerby (1235), another inhabitant of tropical west American waters, resembles *C. gibbiformis* in general outline but it is smaller, possesses finer concentric sculpture and lacks radial sculpture on the left valve. The same characters serve to separate *C. gibbiformis* from *C. granti* Olsson (1236), described from Pliocene beds in Costa Rica.

Another species cited by Olsson (1237) as "*Corbula (Varicorbula)* cf. *bradleyi* Nelson" from beds of Pliocene age in Panama, was said to differ from *C. gibbiformis* in the less elevated form.

SUBGENUS *LENTIDIUM* CRISTOFORI AND JAN

Lentidium Cristofori and Jan, Catalogus, Section II[a], Conchyliologia, Pars 1[a], p. 8; Mantissa, p. 4, 1832. Sole species: *Lentidum* "*maculatum* nob." "Ital. bor." —Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 836, also 838, 1898. "Type *Corbula mediterranea* Costa (+ *maculatum* Jan.)." — Vokes, Bull. Amer. Mus. Nat. Hist., Vol. 86, Art. 1, p. 23, 1945. Type designation by Dall cited.

Corbulomya Nyst, Mém. Cour., Acad. Roy. Sci. de Belgique, Vol. 17, p. 59, 1844. Type (designated by Herrmannsen, Indic. Gen. Malacozoo., Vol. 1, p. 308, 1847): "Typus: *Corbula complanata* Sow."—Cossmann and Peyrot, Act. Soc. Linn. Bordeaux, Tom. 63 (Conch. Néogén. l'Acquitaine, Tome 1, Livr. 1), p. 109, 1909. Designation of type species by Hermannsen cited.—See also Vokes, 1945, pp. 23, 24, 26.

Type species (by monotypy). — *Lentidium maculatum* Cristofori and Jan. [Original description (Mantissa, p. 4): L' tests planata, striata, alba, maculis croceis picta (lat. 2" long. 1 1/2")." Considered by Monterosato (Nom. Gen. Spec. Conch. Mediterr., p. 30, 1884) and by Dall, 1898, to be referable to *Tellina mediterranea* O. G. Costa (Cat. Test. Sicilie, p. XIV, pl. 1, fig. 6a, b, c, 1829). Mediterranean, Recent. See *Corbulomya mediterranea* Costa, Bucquoy, Dautzenberg, and Dollfus Moll. Mar. Rousillon, Tome 2, Fasc. 11 (Pelecypoda, Fasc. 24), p. 585, pl. 85, figs. 24-29 (typical), 30-35 (varieties), 1896. For a thorough diagnosis of *Lentidium mediterranea*, see Vokes, 1945, pp. 23-24, pl. 4, figs. 23-27, 1945. "Recent. Genoa. Italy."]

Range. — Early Eocene (Thanetien) to Recent.

Original description of *Lentidium*. — "Testa compressiuscula subtriangularis, valvulis inaequalibus. Cardo dente unico in utraque valvula, simplici in dextra, plicato in sinistra. Liagmentum partim internum." (Cristofori and Jan, 1832, Mantissa, p. 4.)

Supplementary description. — Shell compressed, trapezoid, feebly concentrically sculptured; the ligament appearing externally through a fissure in the right umbo. (Dall, 1898.)

Remarks. — The sole species listed under *Lentidium* by Cristofori and Jan is *L. maculatum* although a number of authors have cited *Corbula mediterranea* Costa [=*Tellina mediterranea* O.G. Costa, 1829] as the type. It appears probable that the species described by Costa is identical with the one described only briefly by Cristofori and Jan as indicated by Monterosato and by Dall. Bucquoy, Dautzenberg and Dollfus, however, did not include *L. maculatum* in their synonymy of *Corbulomya mediterranea* Costa.

Cossmann and Peyrot considered *Corbulomya* Nyst, to be at least subgenerically distinct from *Lentidium*. Most modern authors consider the two referable to the same genus or subgenus and we follow that practice in the present paper.

Vokes placed *Lentidum* as a genus in a new subfamily Lentidiinae.

Corbula (Lentidium) luteola Carpenter
Plate 55, Figures 1, 2, 5, 6, 15

Corbula luteola Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 661, 637, issued August, 1864. P. 611, "S.Pedro-S. Diego; common near shore." P. 637, indicated as from "The region between S. Diego and S. Pedro." Reprint in Smithsonian Misc. Coll., No. 252, pp. 97, 123, 1872. — Carpenter, Proc. Calif. Acad. Sci., Vol. 3, Pt. 3, p. 207, February, 1865. "Hab. — San Diego, San Pedro, 50 alive at low water." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 203, 1924. "Monterey, California to Lower California," Recent. Also Pleistocene at San Pedro and San Diego, and Pliocene at San Pedro, California.

Corbula luteola var. *rosea* Williamson, Bull. South. Calif. Acad. Sci., Vol. 4, No. 8, p. 120, November, 1905. "Valve on anemone in a rock pool on the old breakwater at Terminal Island," San Pedro, California.

Not *Corbula rosea* Reeve, Conch. Icon., Vol. 2, *Corbula*, species 26, pl. 4, fig. 26, April 1844. "Hab. — ?"

Corbula (Lentidium) luteola Carpenter, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 421, pl. 19, figs. 2, 7, 1931. Various localities cited. Late Miocene to Recent.—Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 94, pl. 25, figs. 15, 16, 1950. Santa Ynez Bay, Lower California, Pleistocene.—K.V.W. Palmer, Geol. Soc. Amer., Mem. 76, p. 117, pl. 15, figs. 13-18, 1958. [Earlier records cited. Type specimens discussed.]

Alodis (Caryocorbula) luteola Carpenter, Hertlein and Strong, Zoologica, Vol. 35, Pt. 4, p. 239, 1950. Monterey, California, to Cape San Lucas, Lower California.

Corbula (Caryocorbula) luteola Carpenter, Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, Calif.) p. 209, fig. 525, 1958. Southern California to La Paz, Lower California, Mexico.

Type specimen. — "Syntypes.—U. S. National Museum, no. 14897 (eight valves." (Palmer, 1958.)

Type locality. — "Recent. San Pedro, California (type)." (Palmer, 1958.)

Range. — Late Miocene to Recent. Recent from Monterey, California, to La Paz Lower California, Mexico, from between tides to 46 meters (25 fathoms). Usually in rocky rubble according to J. Q. Burch (Min. Conch. Club South. Calif., No. 44, p. 29, February, 1945).

Occurrence in San Diego Fm. — L.A.M. Loc. 302, 305, 305A, 318, 319.

Original description. — "Shape of young *biradiata;* small, ashy yellow. Com. Cp." (Carpenter, 1864.)

Supplementary description. — C. t. "C. biradiatae", formâ simulante, sed multo minore; haud obesâ, transversâ, luteo-conereâ, dorsum versum interdum obscure biradiatâ; angulo plus minusve carinato, postice definito; antice rotundatâ, expansa; concentrice crebee sed obtuse lirulatâ; umbonibus obtusis; intus, dentibus minoribus; linea pallii angulatâ, haud sinuatâ; cicatricibus adductoribus callosis; margine t. adultâ postice altero alterum amplectante. (Carpenter, 1865.)

Remarks. — *Corbula luteola* is here reported for the first time from the San Diego Formation. There are about 40 single valves and one specimen with paired valves from Loc. 305 (LAM) near the Mexican boundary. The largest valve is 9 mm long and 5.7 mm high. The specimen with both valves together is 8.1 mm long, 5.3 mm high, the convexity (both valves together) 3.5 mm. A large Recent specimen collected by Henry Hemphill at San Diego is 10.5 mm long, 7.2 mm high, the convexity (both valves together) 4.3 mm, but most Recent specimens are smaller than this one. A few single valves are present in the collections from Loc. 305A, 318 and 319 (LAM).

Corbula luteola has been compared with *C. biradiata* Sowerby (1238) by several authors. Carpenter's species is smaller, generally more compressed, the posterior ventral margin less acutely pointed and the coloration is dull gray or buff.

SUPERFAMILY HIATELLACEA GRAY
FAMILY HIATELLIDAE GRAY (1239)
[SAXICAVIDAE GRAY]

Shell usually ovate or oblong, generally irregular due to distortion, widely gaping behind, byssiferous. Surface smooth but more often with irregular concentric riblets or undulations. Hinge weak, the teeth often obsolete, no laterals, the ligament external, attached to a strong nymphal ridge. Pallial sinus of irregular size, the animal provided with large siphons. Burrowing in deep sand, gravel, or as nestlers or borers in rock. [Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York) p. 425, 1961.] [Late Jurassic to Recent.]

Remarks. — The shells of this family vary greatly in size. The animals are burrowing or nestling forms and, reflecting this habitat, their valves are gaping. There are two small simple teeth in the hinge of the left valve and one in the right. Their shells are usually sculptured only with rude concentric ridges on the shell surface. Members of this family often occur in the intertidal zone but some have been reported to a depth of 448 meters. Kühnelt (1240) discussed the habitat of this group of mollusks and White (1241) described the anatomy of "*Saxicava*" *gallicana* Lamarck.

A list of the species by Tryon (1242) and a revision of the members of this family by Lamy (1243) are useful in a study of this group.

Key to Genera of Hiatellidae

A. Shell with pallial line broken into an irregular series of impressions.
  a. Shell with a median radial depression; roundly subquadrate, nearly as high as long . . . . . *Panomya*
  aa. Shell lacking a median radial depression; rectangular, decidedly longer than high . . . . . *Hiatella*

B. Shell with pallial line entire; very large . . . . . *Panope*

GENUS *HIATELLA* DAUDIN

Hiatella Daudin in Bosc, Hist. Nat. des Coquilles, Vol. 13, AN X [1801], p. 120. [This volume appeared prior to October 23, 1801, according to Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100 Art. 1, p. 33, 1952.] Species cited: *Hiatella biaperta* and *Hiatella monoperta.* — Iredale, Rec. Austral. Mus., Vol. 17, No. 9, p. 406, 1930. — Davies, Tert. Faunas (Thomas Murby and Co.: London), Vol. 1, p. 201, figs. 169, 270, 1935. Paleocene to Recent. Widespread. — Dodge, Nautilus, Vol. 64, No. 1, pp. 29-33, July, 1950. "The type of the genus may be cited safely as *H. biaperta* Daudin + *H. monoperta* Daudin, = *Mya arctica* Linné, by subjective monotypy." — Hertlein and Strong, Zoologica, Vol. 35, Pt. 4, p. 244, December 30, 1950. "Type (here designated): *Hiatella biaperta* Bosc."

Saxicava Fleuriau-Bellevue, Jour. de Physique de Chemie d'Hist. Nat. et des Arts, Tome 54, AN X, p. 354, May 1802. Species cited: "La saxicave striée, *saxicava striata.*" "Perce les rochers des côtes de la Rochelle." —Lamy, Jour. de Conchyl., Vol. 68, No. 3, p. 218, 1924. "qui a pour type *S. striata* Fl. = *Mya arctica* L."

Didonta Schumacher, Essai Nouv. Syst. Test., pp. 42, 125, 1817. Species cited: *Didonta bicarinata* Schumacher, p. 125, pl. 6, fig. 2. Ref. to *Solen minutus* Linnaeus, Chemnitz, Neues Syst. Conchyl.-Cab., Bd. 6, p. 67, Tab. 6, figs. 51, 52, 1782. [= *Mya arctica* Linnaeus.]

Type species (by subsequent designation, Dodge, 1950, p. 31, and Hertlein and Strong, 1950, p. 244). — *Hiatella biaperta* Daudin in Bosc. Hist. Nat. des Coq., Vol. 3 AN X [1801], p. 120, pl. 21, fig. 2. "Se trouve sur la cote de Tranquebar." [= *Mya arctica* Linnaeus.]

Range. — Paleocene to Recent. Recent world-wide, chiefly in cool waters, from the intertidal zone to 2966 meters (1622 fathoms) usually burrowing or nestling in cavities.

Description. — Shell small, irregular, very inequilateral, the young with a cardinal tooth like *Panomya*, the adult with the teeth obsolete; pallial line discontinuous, siphons naked, slightly separated at the tips and in normal

specimens completely retractile, shell burrowing, or nestling in gravel or broken shell, or perforating rocks, corallines, or dead shells like pholads. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 833, 1898.)

Remarks.—This genus has been reported occurring from Paleocene to Recent. Whether or not it occurs in older strata is not certainly known but the genus has been cited, doubtfully, from strata of late Cretaceous age, in Alberta, Canada (1244). *Pseudosaxicava* Chavan (1245) described from beds of late Jurrassic age in France is believed to be an ancient member of the Hiatellidae.

On the west coast of North America, "*Saxicava*" *pholadis* Linnaeus was reported by B. L. Clark from the Poul Creek Formation in southern Alaska of late Oligocene or early Miocene age. In California, the genus has been reported from beds of middle and late Pliocene age as well as in beds of Pleistocene age, and Recent. In Japan species assigned to *Hiatella* have been reported from late Oligocene or early Miocene (1246) to Recent, and in Australia from Miocene to Recent.

Separation of the various species in some cases is difficult because of the variation in the shape of the shell which varies according to whether they burrow or they nestle in cavities. Another problem in connection with identification of these forms is whether some of them should be assigned to *Hiatella* or to juvenile *Panope.*

Dodge (1950) discussed the problem connected with the use of the names *Hiatella* and *Saxicava.* Dall (1247) recently discussed the Hiatellidae and listed the species referred to *Hiatella.*

Hiatella arctica Linnaeus
Plate 56, Figures 15, 17, 18

Mya arctica Linnaeus, Syst. Nat., ed. 12, p. 1113, 1767. "Habitat in Oceano Norvegico." — Hanley, Ipsa Linn. Conch., pp. 28, 461, 1855. — Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 31, 1952. [Discussion of Linnaean species.]

Solen minutus Linnaeus, Syst. Nat., ed. 12, p. 1115, 1867. "Habitat in O. Norvegico. Martin."—Chemnitz, Neues Syst. Conchyl.-Cab., Bd. 6, p. 67, pl. 6, figs. 51, 52, 1782. Iceland; Greenland; Norway, Shallow and deep water.—Hanley, Ipsa Linn. Conch., pp. 32, 462, 1855.

Hiatella biaperta Bosc, Hist. Nat. Coq., Vol. 3, AN X [1801], p. 120, pl. 21, fig. 1. "Se trouve sur la côtes de Tranquebar." [India.]

Hiatella monoptera Bosc, Hist. Nat., Coq., Vol. 3, AN X [1801], p. 120, pl. 21, fig. 1. "Se Trouve sur les côtes de Tranquebar." [India].

Didonta bicarinata Schumacher, Essai Nouv. Syst. Test., p. 125, pl. 6, figs. 2 (a, b), 1817.

Hiatella arctica Linnaeus, Lamarck, Hist. Nat. Anim. s. Vert., Vol. 6, p. 30, 1819. "Habite les mers du Nord, dans le sable, et se rencontre parmi les fucus." — Hertlein and Strong, Zoologica, Vol. 35, Pt. 4, p. 244, 1950. Port Guatulco, Mexico, to Piedra Blanca, Costa Rica. Also Arctic Ocean to Panama, and Atlantic. — Abbott, American Seashells (D. Van Nostrand Co., Inc., New York,), p. 452, fig. 92a, 1954. "Arctic Seas to deep water in the West Indies. Arctic Seas to deep water off Panama."—Richards, Trans. Amer. Philos. Soc., New Ser., Vol. 52, Pt. 3, p. 71, pl. 12 figs. 17-20, 1962. Hudson Bay to North Carolina, Pleistocene. Recent: "Arctic to W. Indies in deep water. Arctic to off Panama in deep water."

Saxicava arctica Linnaeus, Sowerby, Reeve's Conch. Icon., Vol. 20, *Saxicava*, species 1, pl. 1, figs. 1a, 1b, 1c, 1d, 1875. "Arctic regions, British and North American coasts." — Sars, Bid. Kunds. Norges Arkt. Fauna. I. Moll. Reg. Arct. Norvegiae, p. 95, pl. 20, figs. 8a, 8b, 8c, 8d, 1878. Norway and Arctic regions. — Bucquoy, Dautzenberg, and Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 11 (Pelecypoda, Fasc. 24), p. 589, pl. 86, figs. 1-4 (typical); 5-11 (vars.), 1896. Various localities cited.—I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 208, pl. 9, fig. 6; pl. 51, fig. 4, 1924. Arctic Ocean to Panama. Also Atlantic.—Lamy, Jour. de Conchyl., Vol. 68, No. 3, p. 222, 1924. Numerous localitites cited.

Type specimen. — "in the Linnaean cabinet" of the Linnean Society of London (Hanley, Ipsa Linn. Conchyl., p. 28, 1855).

Type locality. — "Habitat in Oceano Norvegico."

Range. — Oligocene to Recent. In western United States, Pliocene to Recent. Recent, Arctic Ocean to Panama (in deep water); to the West Indies (in deep water); northern Europe to the Mediterranean and west Africa. From the intertidal zone to at least 1829 meters (1000 fathoms) and perhaps deeper, usually burrowing or nestling in cavities.

Occurrence in San Diego Fm. — L.A.M. Loc. 107, 305, 305C.

Original description.— M. testa striata: valvulis carinis duabus spinulosis; cardiae edentulo. Habitat in Oceano Norvegico. *F. Zoega.* Testa magnitudine Fabae, rudis, facie Arcae noae, pallida. Antice retuso-planiuscula, parte anteriore obtusissima, posteriore breviore, acutiuscula; pars anterior a natibus excurrit angulis duobus remotis antrorsum subaculeatis. Cavitas interna lactea est. Cardo vix ullus. (Linnaeus, 1767.)

Remarks.—The shell characters generally relied upon to identify *Hiatella arctica* and *H. pholadis* (1248) were summarized by Dodge (1952, pp. 32-33) as follows:

"*Saxicava arctica:* One tooth in the right valve and two in the left. Roughly quadrate in form and longer in proportion to width than *rugosa.* Spines on young or unworn specimens." [See illustrations by Sars, 1878, and Abbott, 1954.]

"*Saxicava pholadis:* A completely edentulous form. The concentric sculpture is weaker than in either of the others. Less quadrate than *arctica.* Spineless. More evenly rounded at the ends than the other two."

Hiatella arctica is here reported for the first time from the San Diego Formation. Two right valves about 6 mm long are present in the collection from Loc. 305 (LAM); two valves, the larger one about 5 mm long, from Loc. 305A (LAM); one small valve from Loc. 305C (LAM); and one very small left valve from Loc. 318 (LAM). All these are from localities near the Mexican boundary. A specimen with both valves from Loc. 107 (LAM) is 10 mm long.

The shell of this species is reported (Abbott, 1954) to attain a length of 76 mm (3 inches). We have seen a left valve 68.5 mm long and 35.3 mm high which was taken

by R. R. Talmadge from a cavity in a sponge dredged off Crescent City, Del Norte Co., California [Loc. 40733 (CAS)], in 750 meters (410 fathoms). Richards (1249) pointed out in a discussion of *Hiatella arctica* that "the heavy, coarse variety typical of the Pleistocene is limited to Arctic and sub-Arctic seas." Elton and Baden-Powell (1250) mentioned that there appears to be a tendency for the shell of *H. pholadis* to develop a thicker shell in the colder waters of its distribution also a tendency to be typically longer in warmer waters.

The species described as "*Saxicava*" *antarctica* Philippi (1251) is very similar to *H. arctica* and Dall (1252) expressed doubt that the South American species is distinct. We have noticed no difference, except in size, between specimens referred to *H. arctica* from off Costa Rica and those from boreal waters. Olsson (1253), however, believes it best to refer the Panamanian forms to *H. solida* Sowerby (1254).

The type locality originally cited for *H. solida* was Santa Elena, Ecuador. Dall (1255) stated that there is doubt concerning this locality and he mentioned that Sowerby in 1875 cited no locality for this species. He discussed (pp. 224-226) *H. arctica* and *H. solida* and considered the latter to be a species of southern South America but he mentioned that young shells of the two are indistinguishable. He observed that shells of *H. arctica* to a length of 15 mm have well developed hinge teeth but that these later become completely obliterated by an overgrowth of the nymph when 28 mm long whereas shells of *H. solida* 20 to 35 mm long still retain obvious hinge teeth. We have not had specimens from southern South America for comparison but most specimens of *H. arctica* 20 to 44 mm long which we have studied are virtually edentulous.

Hiatella arctica was reported from Germany by von Koenen (1256) from strata of middle Oligocene age and by Görges (1257) from beds of late Oligocene age. Cossman and Peyrot (1258) discussed its occurrence in beds of Miocene age in France. They mentioned that records of *H. rugosa* in beds of Miocene age are probably referable to *H. arctica* but pointed out that *H. vera* Deshayes from strata of Eocene age is a distinct species.

Many records of *Hiatella arctica*, subspecies such as *H. arctica bilineata* Conrad (1259), and others cited as *H. arctica* but later designated as distinct, such as *H. orientalis* Yokoyama (1260), have been reported from other parts of the world. The relationship of these various forms must await a careful study of the group.

The present record of the occurrence of *H. arctica* in the San Diego Formation is the earliest, geologically, reported from California. Soper and Grant (1261) reported this species from strata at Fifth and Hope streets in Los Angeles, considered to be of late Pliocene age.

Dall (1262) reported *H. arctica* from several localities in southwestern Alaska from beds assigned Miocene age. MacNeil (1263) later discussed these occurrences but did not find specimens to verify the age assignment. Dall (1264) also identified this species from beds probably of Pliocene age, in Lituya Bay, in southeastern Alaska. It also has been reported (1265) from the Daishaka Pliocene in Japan.

Hunter (1266) discussed the boring habits of *H. arctica* and more recently Ockelmann (1267) summarized much information concerning this and similar forms.

GENUS *PANOPE* MÉNARD

Glycimeris Lamarck, Mém. Soc. Hist. Nat. Paris, Vol. 1, p. 83, 1799. Sole species, "*Mya glycimeris.* Born. mus. t. 1, f. 8."

Not *Glycymeris* Da Costa, 1778.

Panope Ménard de la Groye, Mémoire sur un nouveau Genre de coquille bivalve-équivalve de la famille des solenoides, pp. 16, 31, January, 1807. Two species described, "*P. Aldrovandi.*", p. 31 (synon. included *Mya glycimeris* Born), Recent, Europe, Mediterranean, Spain; and "*P. Faujas,*" p. 33, pl. 12. "Se trouve fossile en Italie, à six milles au sud de Plaisance, dans le depot du Stramonte." Also reported Recent in Mediterranean; Spain.—Dall, Proc. Malacol. Soc. London, Vol. 10, Pt. 1, pp. 34-35, 1912.—Vokes, Jour. Paleo., Vol. 30, No. 3, pp. 766-777, 1956.

Panopaea Ménard, Lamarck, Extr. Cours. Zool, p. 108, 1912. Type designated by Children (Quart. Jour. Sci. Lit. and Arts.,Vol. 14, p. 83, pl. 4, fig. 27, October, 1822): "*P. aldrovandi* (*Mya glycimeris* Linn.)".

Type species (designated by Schmidt, Versuch Conchyl.-Samml., p. 177, 1818). — "Type. *Mya glycimeris*" [Born, Index Mus. Caes. Vindobonensis, p. 10, 1778. No locality cited. (Ref. to Aldrovandi, Tes., l. 9, pp. 473, 474; Lister, Hist. Conch., l. 3, fig. 258; Gualtieri Test., t. 9 [90], fig. A.) — Born, Test. Mus. Caes. Vindobonensis, p. 20, pl. 1, fig. 8, 1780. For references to and a discussion of this species see Lamy, Jour. de Conchyl., Vol. 68, No. 4, pp. 267-269, 1925.]

Range. — Late Jurassic; Cretaceous to Recent. Recent from the littoral zone to 165 meters (90 fathoms).

Description. — Shell usually large, elongated, ventricose, anterior end rounded, posterior end truncated, gaping (more so posteriorly); beaks subcentrally placed; rather coarse concentric sculpture; hinge with one cardinal tooth in each valve; ligamental ridge large; pallial sinus well developed.

Remarks. — The earliest geologic occurrence of *Panope* is not known with certainty because of the lack of knowledge concerning the characters of the hinge and other features of ancient species which may or may not be referable to this genus. *Panope brockworthensis* from the inferior Oolite, late Jurassic of England, was described by Cox (1268) who discussed the difficulties of determining the genera of many Mesozoic fossils. He pointed out that some of those fossil forms might be referable to the genus *Myopsis* L. Agassiz for which genus he selected *Mya mandibula* Sowerby as type. *Pleuromya* L. Agassiz, confined to the Mesozoic, has a smaller posterior gape and a depression which extends from the umbos to the anterior end and the shell is nacreous rather than porcelaneous.

Five species of *Panope* have been recorded occurring in Tertiary strata of California. One Recent subspecies of the California form has been described from Scammon's Lagoon, Lower California, and one species from the Gulf of California. Others have been described from the Cenozoic of South America.

Lamy (1269) published a useful summary of the Recent species of *Panope*.

About a dozen Recent species of this genus occur in the present seas mostly in cool and temperate water

but a few occur in subtropical waters. These mollusks usually burrow in sandy mud which is exposed at low tide.

Vokes (1270) discussed the name *Glycimeris* Lamarck (not Da Costa), an earlier name for *Panope*.

Deschaseaux (1271) placed *Panope* in the family "Panopaeidae Zittel".

Panope generosa Gould
Plate 56, Figures 19, 20

Panopaea generosa Gould, Proc. Boston Soc. Nat. Hist., Vol. 3, p. 215, May, 1850. — Gould, U.S. Explor. Exped (Wilkes), Vol. 12, Mollusca, p. 385, 1852, Atlas, p. 13, pl. 34, figs. 507, 507a, 507b, 1856. — J.P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 173, 182, 1912. "San Diego-Purisima. Pliocene." — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 205, pl. 2, figs. 1, 2, 1924 (reproduction of Gould's original figures 507a, 507b). "Puget Sound to San Diego, California." Also Pleistocene and Pliocene.

Panopea generosa Gould, Arnold, U.S.G.S., Bull, 396, p. 31, pl. 18, fig. 4, 1909. "Upper Etchegoin formation." also Upper Miocene to Recent. Also Bull. 398, pl. 40, fig. 4, 1910. (Same figure). — Reagan, Trans. Kansas Acad. Sci., Vol. 22, p. 204, 1909. "Purisima-San Diego" formation of California.

Panope genrosa Weymouth, Calif. State Fish Game Comm., Fish Bull. No. 4, p. 63, pl. 18, fig. 2, 1920. California coast.—I.S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 63, pl. 16, figs. 1, 2, 1924. [Reproduction of Gould, 1856, pl. 34, figs. 507a, 507b.] Vancouver Island to San Diego, California.—Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 82, 1929. "San Diego Pliocene."—Fitch, Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 92, fig. 58, 1953. "Range: Forrester Island, Alaska, to Scammons Lagoon, Baja, California."

Panope (Panope) generosa Gould, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 424, pl. 21, figs. 12a, 12b, 1931. Miocene to Recent. [Not all the synonymy.]

Panope (Panope) abrupta Conrad, Moore, San Diego Soc. Nat. Hist., Occas. Paper 15, p. 42, pl. 19, 1968. Balboa Park, San Diego, Pliocene.

Type specimen.—Holotype No. 5894, United States National Museum.

Type locality. — "Hab. Puget Sound, Oregon." [Washington.]

Range. — "cf." Early Miocene (Vaqueros). Middle Miocene (Temblor) to Recent. Recent from Forrester Island, Alaska, to Scammon's Lagoon, Lower California, Mexico, between tides, burrowing to a depth of four feet or more in unshifting sandy mud beaches in bays, estuaries and sheltered areas. Burch reported dredging empty shells at a depth of 46 meters (25 fathoms) off Redondo Beach, California (Min. Conch. Club South. Calif., No. 44, p. 30, February, 1945.)

Occurrence in San Diego Fm. — C.A.S. Loc. 1400, 1402, 1418, 28885, 28889. L.A.M. Loc. 107, 305, 305A, 319. S.D. Loc. 4, 27, 29 [=Loc. 1402 (CAS)]; Loc. 34, Cat. nos. 6386, 6387, 6389, Pacific Beach (casts). U.C.L.A. Loc. 2359.

Original description: Test magna, ponderosa, calcarea, sub-quadrilateralis, concentricè unduloso-plicosa, epidermide flavido, rugoso induta, anticè rotundata, posticè truncata et valdè hians; umbonibus submedianis, acutis, elevatis, undulatis: cardo gracilis, dente elevato obliquè triangulari instructus: cavitas ad apicem profunda; cicatrice musculari lato, benè impresso; sinu siphonali minimè profundo. Long. 6; alt. 4; lat 3 poll. (Gould.)

Remarks: A number of specimens from the San Diego Formation, in various states of preservation, agree in all observable characters with Recent *Panope generosa*. The largest specimen (incomplete), from Loc. 305 (LAM) is 135 mm long. Another from the same locality is 98 mm long, 63 mm high, convexity (both valves together) 41.6 mm. A specimen from Loc. 305A (LAM) is 114 mm long and 75 mm high. Many fragments from these two localities are present in the collections of the Los Angeles County Museum. The largest specimen from the San Diego Formation in the collections of the California Academy of Sciences is 102 mm long (incomplete). The largest Recent specimen in the Academy's collection is one collected in Puget Sound by Henry Hemphill, which is 186.9 mm long, 101.5 mm high, convexity (both valves together) 73.2 mm. Fitch (1953) mentioned that huge Recent specimens of this mollusk (including the animal) may weigh eight pounds.

There is variation in the shape of the fossils in the present collections. The valves of some specimens are more convex than others and on some the posterior dorsal margin is nearly straight, on others concave. Similar variations can be observed in a series of Recent specimens and are no doubt the result of the burrowing habit of this mollusk.

Panope generosa solida Dall (1272) was described with the locality cited as San Francisco, California. According to Dall, this differs from the typical form in that the ligamentary attachment is twice as long and the pallial sinus is deeper. Experienced collectors have not since found *P. generosa* nor any variety of it in that area and according to Packard (1273) no specimens were taken by the *Albatross* in their dredgings in and near San Francisco Bay. The illustration of this form given by Oldroyd (1274) is that of a broad, subquadrate shell and it was said to occur with the typical form throughout most of its range but Keen (1275) pointed out that there are questions concerning the specimen illustrated as type by Oldroyd.

Panope globosa Dall (1276) described from the north end of the Gulf of California was said to be characterized by the shell "of a yellowish white color, shorter, thinner, and more globose than *P. generosa* and probably distinct."

We have examined two valves of this form collected by E. P. Chace on the beach about 20-25 miles south of San Felipe, Lower California. These are more globose and the posterior end is narrower than comparable specimens of *P. generosa*, and apparently represent a distinct species. The right valve is 151 mm long, 106 mm high, the convexity (one valve) 38 mm.

Records of *P. generosa* from beds of Pliocene age in the Gulf of California region are probably referable to *P. globosa*.

Several named forms from the Cenozoic of western

North America are either identical with or very closely allied to the Recent species. The form from the middle Miocene at Astoria, Oregon, named *Mya abrupta* (1277) by Conrad may be identical with *Panope generosa*. Moore (1278) examined the type specimen of Conrad's species and considered *Panope generosa* to be identical and placed the latter in the synonymy of *P. abrupta*. She described the type specimen of *P. abrupta* as a thin-shelled form 65.8 mm long and 39.2 mm high. This is smaller than most adult shells of *P. generosa*. The west American species of *Panope* are in need of monographic study. For the present we use the name *Panope generosa* for Recent and for the Pliocene specimens mentioned in the present report.

There have been differences of opinion by authors concerning the Miocene species named *Glycimeris estrellanus* (1279) by Conrad. The original figure is that of an imperfectly preserved specimen, and there is doubt concerning its specific characters. Moore (1963, p. 83-84) placed it in the synonymy of *P. abrupta*. Clark (1280) discussed what he considered to be the differences between this fossil and the Recent *Panope generosa*. Later the same author proposed the name *Panope ramonensis* (1281) for a fossil from near Walnut Creek, California, in beds which he referred to late Oligocene age. In the synonymy of this species he cited the "*Panope* cf. *estrellana* Conrad" of his earlier work.

Panope tenuis Wiedey from Temblor strata of middle Miocene age and *P. taeniata* Dall described from beds of Pleistocene age at Magdalena Bay, Lower California, are both much narrower posteriorly than the Recent species described by Gould. The type specimen of *Panope similaris* Dall and Ochsner from Pliocene strata in the Galapagos Islands also is more attenuated than typical *P. generosa*.

The species occurring in Japan from Miocene to Recent, cited by some authors under the name of *Panope generosa*, is now referred to *Panope japonica* A. Adams (1282)

GENUS *PANOMYA* GRAY

Panomya M. E. Gray, Fog. Moll. Anim., Vol. 5, p. 29, pl. 346, fig. 1, 1857. Sole species, "*P. norvegica*, t. 346, f. 1." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 832. 1898. "Type *Panopea (Mya) norvegica* Spengler."—Lamy, Jour. de Conchyl., Vol. 68, No. 4, p. 261, 1925. Type, *Mya norvegica* Spengler. = *Panopaea spengleri* Valenciennes. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 425, 1931. Type (by monotypy), *Mya norvegica* Spengler.

Type species (by monotypy). — *Panomya norvegica* Spengler [= *Mya norvegica* Spengler, Acta Soc. Hist. Nat. Hafn., Vol. 3, p. 46, pl. 2, fig. 18, 1793. (Not *Mya norvegica* Gmelin, 1790, which is a *Lyonsia*.) Illustrated by M. E. Gray, 1857, pl. 346, fig. 1.—Gould, Rept. Invert. Massachusetts (Boston), (edited by W. G. Binney), p. 52, fig. 373, 1870 (as *Panopaea arctica* Lamarck). — Sowerby, Reeve's Conch. Icon., Vol. 19, *Panopaea*, sp. 7, pl. 5, fig. 7, 1873 (as *Panopaea spengleri* Valenciennes.) — Davies, Tertiary Faunas (T. Murby & Co.: London), p. 201, fig. 269 (p. 196), 1935. — N. Macginitie, Proc. U. S. Nat. Mus., Vol. 109, No. 3412, p. 189, pl. 19, fig. 1; pl. 25, figs. 6, 8, 1959 (as *Panomya arctica)*].

Range.—Late Oligocene or early Miocene to Recent. Recent, from the intertidal zone, occasionally 46 to 600 meters (25 to 328 fathoms).

Description. — Shell differs from *Panope* in that it is shorter in proportion to the height, in the presence of a pronounced medial radial depression and in that the pallial line is broken into an irregular series of rounded impressions.

Remarks.—This genus has been reported from Japan from late Oligocene or early Miocene to Recent: from the northeastern Pacific from late Miocene or Pliocene to Recent and in the Arctic region and in northern Europe from Pliocene to Recent. It is essentially an inhabitant of intertidal or shallow boreal and Arctic waters. However, the type species, *Panomya arctica* in the Atlantic, has been reported (1283) from depths of 530-600 meters (290-328 fathoms).

At the present time *Panomya* has not been reported living south of Puget Sound along western north America, but during Pliocene time it occurred as far south as San Diego, California. The fossil and Recent species of *Panomya* from Japan have been discussed by Kanno (1284).

A large specimen of *Panomya gigantea* Kanno from strata of Pliocene age in Japan, is 137 mm long and 98 mm high.

Panomya cf. *P. beringiana* Dall
Plate 56, Figures 12

The following references, type locality and range refer to typical *P. beringiana*.

Panomya beringiana Dall, Proc. U. S. Nat. Mus., Vol. 52, No. 2183, p. 416, December 27, 1916. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 207, 1924. Type locality cited. Range: eastern Bering Sea. — Woodring, Bramlette, and Kew, U. S. G. S., Prof. Paper 207, p. 85, pl. 33, figs. 13, 14, 1946. Timms Point Silt, San Pedro, Pleistocene.

Type specimen. — No. 212875, United States National Museum.

Type locality. — "Station 3529, near the Pribiloff Islands, in 56 fathoms."

Range. — Late Pliocene to Recent. Recent from the Aleutian Islands to Puget Sound in 102 to 146 meters (56 to 80 fathoms). Probably also in Japan.

Occurrence in San Diego Fm. — C.A.S. Loc. 1418. L.A.M. Loc. 305.

Original description. — Shell resembling *P. arctica* Lamarck, in a general way, but thinner, less cylindrical, much larger, and proportionately shorter. Length, 130; height, 80; diameter, 50 mm. (Dall, 1916.)

Remarks.—Two specimens from the San Diego Formation in the collections of the California Academy of Sciences are referable to the genus *Panomya*. The specimens are incomplete casts which retain only portions of the shell. The larger of these is 52.5 mm long and 46 mm high. A very well developed radial median depression is present on these fossils. A fragment of a thin shell 30 mm long, from Loc. 305 (LAM), appears to be referable to the

same species.

Several species of *Panomya* have been recorded from boreal west American waters. The earliest valid name appears to be *Glycimeris arctica* Lamarck (1285). *Mya norvegica* Spengler, 1793, is a synonym of Lamarck's species because of an earlier *Mya norvegica* Gmelin, 1790, which is referable to the genus *Lyonsia.*

Dall in 1898 described *Panomya ampla* (1286) in the synonymy of which he placed "*Panopaea norwegica* Spengler" illustrated by Middendorff (1287). Dall characterized this species as follows: "This differs from *P. norvegica* by its much more heavy and rude shell, with a more expanded posterior region, and flatter, more irregular valves." His illustration is that of a decidedly trigonal valve, the dorsal margin nearly straight and the anterior end very narrow in comparison to the broad posterior end. MacNeil (1288) in 1943 cited *P. ampla* from beds of Pliocene and perhaps Pleistocene age from near Nome, Alaska. His illustration shows a right valve which anteriorly tapers to a blunt point. Oldroyd (1289) illustrated a shell under the name of *Panomya ampla* from Puget Sound the shape of which is more that of *P. beringiana* but according to MacGinitie (1959, p. 189) this illustration represents "*P. turgida (=P. arctica).*" Grant and Gale (1290) also illustrated a shell from the same region which, according to Woodring (1946, p. 85) resembles *P. beringiana.* The illustration by Kira (1291) of a species from Japan under the name of *P. ampla* likewise appears to be referable to *P. beringiana.* The illustrations of Grant and Gale and that of Kira were all referred to *P. arctica* by MacGinitie, who, however, did not refer to *P. beringiana.*

The next species in chronological order of date of description is *Panomya (ampla* var.*?) chrysis* Dall (1292), a fossil from the Empire beds of Pliocene age at Coos Bay, Oregon. Dall considered this to differ from *P. ampla* "from which the valves differ in being thin, instead of enormously thickened, and in wanting the conspicuous anterior oblique truncation of the living species." Howe (1294) placed this in the synonmy of *P. ampla* and this arrangement was followed by Grant and Gale. We have examined a cast of the type specimen of the fossil from Coos Bay, Oregon, and can add nothing to Dall's observations on that form.

In 1916 Dall described two forms from Alaska, *Panomya beringiana* and *Panomya arctica* var. *turgida. Panomya beringiana* was described as differing from *P. arctica* in the thinner shell, less cylindrical form, and in the larger size and proportionally shorter shell. The illustration of species by Woodring, Bramlette, and Kew, shows a shell which is anteriorly attenuated and rounded at the end and the anterior dorsal margin slopes downward and does not form an almost straight line with the posterior dorsal margin as does that of *P. ampla.*

Panomya arctica turgida Dall (1294) was described as "shell very similar to the North Atlantic form but very much more capacious and larger. Length, 90; height, 60; diameter, 48 mm. Cat. No. 151334, U. S. N. M." Clark (1294) illustrated a fossil from the Yakataga Formation in southeast Alaska of late Miocene or early Pliocene age. This form appears to be much more elongate, more cylindrical, and to have a thicker shell than do the fossils from the San Diego Formation. According to Woodring, *P. turgida* is more inflated and has a less conspicuous median groove than the late Pliocene or Pleistocene fossils from the Los Angeles district which he referred to *P. beringiana.*

There has been confusion in the literature concerning the three forms described by Dall. Woodring (1946, p. 85) stated that records of *P. ampla* and *P. turgida* from beds of Pliocene and Pleistocene age in southern California are referable to *P. beringiana.* Eyerdam (1296) pointed out that a species in his collection from Victoria, British Columbia, formerly believed to be *P. ampla,* was later identified by A. M. Keen as *Panomya turgida.* Schlesch (1297) considered *P. turgida* to be a virtual synonym of *P. norvegica.*

From the foregoing it appears that the several named forms of *Panomya* in the northeastern Pacific are quite similar and that too many names have been proposed for them. A species from Japan compared with *P. ampla* was described as *Panomya nipponica* by Nomura and Hatai (1298). Habe (1299) recorded *P. ampla* from Japan and stated "as the writer observed all kinds of transitional forms among *P. ampla, P. turgida* and *P. nipponica* in many species from Nemoro and Akkeshi, those three species seem to be merely the local or individual forms of one species." Kanno (1957, p. 13) concurred in this opinion.

The imperfect preservation of the fossils from San Diego makes identification of the species doubtful. The median depression on these fossils is more pronounced than it is on Dall's type specimen of *P. ampla chrysis* Dall from the Empire beds at Coos Bay, Oregon.

We compare the present fossils to *P. beringiana,* whose shell characters are well known, because of the general similarity, the pronounced median groove and thin shell. Furthermore, what is probably this species has been recorded occurring in the Careaga Sandstone of Pliocene age in the Santa Maria district (1300) and Faustman (1301) has recorded it from strata of middle Pliocene age in Humboldt Co., California. We have observed a lot of 16 specimens of *P. beringiana* from near the latter locality which were collected by Bruce Martin at Loc. 119 (CAS).

SUPERFAMILY PHOLADACEA RAFINESQUE (1302)
FAMILY PHOLADIDAE RAFINESQUE (1303)

Shells with a narrow, slit-like to nearly circular pedal gape, which may or may not be closed by a callum in the adult stage. Anterior portion of the valves imbricate and often ribbed. This portion is often separated from the posterior portion by an umbonal-ventral sulcus. Hinge teeth usually lacking, a small chondrophore present in some forms, ligament if present, internal. Anterior dorsal margin of the valves reflected, forming the attachment area for the externally placed anterior adductor muscle. In the adult stage of most forms the chitinous cover (cephalic hood) of the anterior adductor muscle is covered by accessory plates or by a dorsal extension of the callum. The total number of accessory plates in any one species may vary from one in *Barnea* and *Zirfaea* to four in *Martesia* and *Parapholas.* Apophyses are present in the Pholadinae and Martesiinae, but absent in the Jouannetiinae and Xylophagainae. Pallial sinus usually deeply in-

set. (Adapted from Turner.) Jurassic to Recent.

Remarks. — The members of this group of mollusks occur world wide and live from the intertidal zone to a depth of 457 meters (250 fathoms). They burrow into rock, wood, or other shells. The greatest number of genera occur in warm temperate, subtropical and tropical waters. Turner pointed out that the greatest development of this group is in the eastern Pacific where there are 13 genera and 23 species in comparison to 8 genera and 13 species in the western Atlantic.

An excellent work by Turner (1304) deals with the Pholadidae of the western Atlantic and of the eastern Pacific. Lamy (1305) discussed the species in the collections of the Natural History Museum in Paris.

Key to Genera of Pholadidae

A. Callum present; shell gaping along posterior half of dorsal and ventral margins . . . . . *Penitella*

B. Callum lacking; shell gaping only at both ends . . . . . *Zirfaea*

GENUS *ZIRFAEA* GRAY

Zirfaea Gray, Synop. Brit. Mus., ed. 42, p. 150, 1840. [No description nor species.] — Gray, Synop. Contents Brit. Mus., ed. 44, p. 76, 1842. [Brief description, no species cited.] [Concerning the preceding references, see Iredale, Proc. Malacol. Soc. London, Vol. 10, Pt. IV, pp. 298, 303, 309, March, 1913.] — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 432, 1931. "Type (by subsequent designation, Gray, 1847), *Pholas crispatus* Linnaeus." — Turner, Johnsonia, Vol. 3, No. 33, p. 54, 1954. "Genotype, *Pholas crispata* Linné, subsequent designation, Gray, 1847."

Thurlosia Catlow and Reeve, The Conchologist's Nomenclator, p. 3, 1845. "*Thurlosia crispata*, Leach" cited in synonymy of "*P. crispata*, Linn., Syst. Nat. p. 111; Enc. méth. pl. 169, f. 5-7."

Zirphaea Leach, Synop. Moll. Great Britain, pp. 250, 252, 1852. *Zirphaea crispata* Linnaeus and synonymy cited.

Type species (by subsequent designation, Gray, Proc. Zool. Soc. London for 1847, p. 188, 1847).—"*Ph. crispata*" [= *Mya crispata* Linnaeus, Syst. Nat.,ed. 10, p. 670, 1758. Ref. to "List. angl. t. 5. f. 38" and "app. t. 2. f. 7." "Habitat in O. septentrionali." Also illustrated by Sowerby in Reeve's Conch. Icon., Vol. 18, *Pholas*, pl. 3, fig. 9, 1872. "Hab. Great Britain." — Turner, 1954, p. 55, pls. 1, 3, 28, 29, and pl. 30, figs. 1-3].

Range. — Middle Miocene (Temblor) to Recent. Recent in boreal and warm temperate waters of the Atlantic and Pacific oceans of the northern hemisphere; boring in consolidated mud or clay, rock, occasionally wood, from the intertidal zone to 128 meters (70 fathoms).

Description. — Shell oval in outline, beaked anteriorly, rounded to truncate posteriorly, widely gaping at both ends and having a sulcus extending from the umbo to the ventral margin. There is a single dorsal accessory plate, the mesoplax, which is small and more or less triangular in outline. Apophyses solid, strongly curved, broadened and often spoon-shaped at the free end. (Turner, 1954.)

Remarks. — Two species of *Zirfaea* have been reported from beds of late Tertiary age in California, one of which now lives in west American waters. *Zirfaea* is here reported from the San Diego Formation for the first time.

Zirfaea cf. *Z. pilsbryi* Lowe

The following references, type locality, range and description refer to typical *Z. pilsbryi.*

Zirfaea gabbi Tryon, I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 210, pl. 36, fig. 1, 1924. "Bering Sea and islands south to San Diego." [Not the locality "Japan."] Also Pleistocene.

Not *Zirphaea gabbii* Tryon, Proc. Acad. Nat. Sci. Philadelphia, Vol. 15, p. 144, pl. 1, fig. 1, 1863. "Hab. Coast of Japan?"

Zirfaea pilsbryi Lowe, Nautilus, Vol. 45, No. 2, p. 53, pl. 3, figs. 1, 2, October, 1931. "Bolinas, California." — Morris, Field Guide to Shells of the Pacific Coast and Hawaii (Houghton Mifflin Co.: Boston, Massachusetts), p. 63, pl. 18, fig. 7, 1952. "Bering Sea to Lower California." — Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 95 fig. 61, 1953. "Nunivak Island, Alaska, to San Juanico Bay, Baja California." — Turner, Johnsonia, Vol. 3, No. 33, p. 58, pl. 30, figs. 4-9; pls. 31-34, 1954. Various localities cited. Range same as cited by Fitch.

Type specimen. — No. 50809, Academy of Natural Sciences of Philadelphia.

Type locality. — "from Bolinas, California."

Range. — ? Late Miocene; Pliocene to Recent. Recent from Nunivak Island, Alaska, to San Juanico Bay, Lower California, Mexico, from the intertidal zone to 24 meters (13 fathoms); boring in mud and in clay banks to a depth of 25 to 30 cm., occasionally in water-logged wood.

Occurrence in San Diego Fm. — L.A.M. Loc. 305.

Original description of *Z. pilsbryi.* — Shell large, transverse, obliquely divided by a shallow furrow proceeding from the umbonal apex to the basal margin and forming a corresponding rib on the internal surface of valve. Posterior to the furrow the shell is marked only by growth wrinkles; on the anterior half they appear as sharp ribs which are produced into sharp spines in unevenly spaced radiating lines continuing to the sharply crenulated margin. Diameter of type, 36 mm.; alt., 37 mm.; length 75.5 mm. (Lowe.)

Remarks. — The present record of *Zirfaea* cf. *Z. pilsbryi* from the San Diego Formation is based upon fragments, the largest about 15 mm long. These retain the widely spaced concentric sculpture surmounted by fine spines such as occur on the anterior dorsal portion of valves of Recent *Z. pilsbryi.*

The shell of Recent *Z. pilsbryi* is longer and narrower and the internal apophyses broader and more concave than those of the shell of *Z. crispata* Linnaeus, a European species.

Turner (1954) gave a thorough description of *Z. pilsbryi* and MacGinitie (1306) discussed its ecology and

boring habits. More recently Yonge (1307) also remarked on the boring habits of this species.

A subspecies, "*Zirfaea gabbi* Tryon *femii*" Adegoke (1308), was described from the San Joaquin Formation of late Pliocene age in the Coalinga district. It is said to differ from the typical subspecies in the more elongated outline, more widely spaced concentric lamellae on the anterior end and in other features.

GENUS *PENITELLA* VALENCIENNES

Penitella Valenciennes, in Abel du Petit-Thouars, Voyage autour du monde sur la Frégate La Vénus, Atlas de Zoologie, Mollusques, pl. 24, 1846. [No text.] Species cited: "*Penitella conradi.* (Nob.)," "*Penitella xilophaga.* (Nob), "*Penitella tubigera.* (Nob.)," — Turner, Johnsonia, Vol. 3, No. 34, p. 70, March 29, 1955. "Genotype, *Penitella conradi* Valenciennes, subsequent designation Habe 1952."

Type species (subsequent designation by Habe, Gen. Jap. Shells, Pelecypoda, No. 3, p. 243, May, 1952).— "Type species: *Penitella conradi* Valenciennes."

Range. — Late Oligocene (San Ramon) to Recent in the north and northeast Pacific. Recent from intertidal zone to a depth of 79 meters (43 fathoms).

Description. — Shells small to moderate in size, the larger species reaching about 95 mm (about 3 3/4 inches) in length, oval in outline, divided into two distinct regions by an umbonal-ventral sulcus and producing a callum in the adult stage. Shell beaked and widely gaping anteriorly in the young stage, with a nearly circular pedal gape. Valves rounded to truncate and closed posteriorly, the siphon being capable of complete retraction within the shell. Umbonal reflections variable, ranging from those which are thin and very closely appressed so that the sculpture of the shell shows through, to those which are heavy and free anterior to the umbos. Protoplax lacking, being replaced by the dorsal extension of the callum. Mesoplax transverse, in one piece and, in young specimens, very similar to that found in *Zirfaea.* In the adult, a dorsal portion is added to the mesoplax which grows forward and encloses the posterior portion of the anterior adductor muscle. Metaplax and hypoplax lacking, siphonoplax variable, present or absent. Siphonal tube lacking. (Turner.)

Remarks.—The shell of *Penitella* differs from that of *Pholadidea* Turton (1309) in that the mesoplax is in one piece rather than divided longitudinally into two more or less triangular pieces, the two portions of the siphonoplax are not fused and are often diverging, the apophyses are thick, expanded and often blade-like at the free end, whereas those of *Pholadidea* are small, narrow and fragile.

Five species of *Penitella* live in the eastern Pacific in the region between Bering Island, Siberia, and Bahía Tórtola (Turtle Bay), Lower California, and an equal number of species has been reported from the late Tertiary in the same region. Two of these are present in the collections from the San Diego Formation. Two Recent species and one fossil form have been reported recently from Japan (see Adegoke, Proc. Calif. Acad. Sci., Ser. 4, Vol. 35, No. 1, p. 18, 1967.)

Key to Species of *Penitella*

A. Shell short and globose; mesoplax pointed anteriorly, truncated posteriorly; maximum length about 33 mm . . . . . *conradi*

B. Shell elongately ovate; mesoplax pointed posteriorly, truncated anteriorly; maximum length about 93 mm . . . . . *penita*

Penitella conradi Valenciennes
Plate 57, Figures 5, 13

Penitella conradi Valenciennes, in Abel du Petit-Thouars, Voy. autour du Monde sur la Frégate La Vénus, Atlas de Zool. Moll., pl. 24, fig. 1, 1846. [No decription nor locality.]—Lamy, Bull. Mus. Nat. Hist. Nat., Paris, Vol. 27, No. 2, p. 179, 1921. Monterey, California. — Lamy, Jour. de Conchyl., Vol. 69, No. 3, p. 152, 1926. Earlier records cited. — Turner, Johnsonia, Vol. 3, No. 34, p. 75, pls. 43-46, 72, figs. 1, 2, March 29, 1955. Range, "From Gualala, Mendocino County, California south at least as far as Bahía San Bartolomé, Baja California."

N[avea]. subglobosa Gray, Ann. Mag. Nat. Hist., Ser. 2, Vol. 8, No. 47, p. 385, November, 1851. "Hab. California, in a hole in a shell."

N[avea]. Newcombii Tryon, Amer. Jour. Conch., Vol. 1, Pt. 1, p. 39, pl. 2, figs. 1-3, February 25, 1865. "Habitat Australia." In Vol. 1, Pt. 3, p. 285, July 1, 1865, it is stated "Dr. Newcomb informs us that the locality of *Navea Newcombii,* stated in our description of that species, (p. 39) is erroneous. The specimens were extracted from a *Haliotis* from Lower California."

Penitella parva Tryon, Amer. Jour. Conch., Vol. 1, Pt. 1, p. 39, pl. 2, figs. 4, 5, February 25, 1865. "Habitat, Lower California, in Haliotis."

Type specimen. — Muséum Nationale d'Histoire Naturelle de Paris.

Type locality. — Monterey, California (from label with type specimen) (Lamy).

Range. — Middle Pliocene to Recent. Recent from Vancouver Island, British Columbia, to Bahía Tórtolo (Turtle Bay), Lower California, and possibly further, often boring in shell of *Haliotis,* or in clay or soft rock, from intertidal zone to 18 meters (10 fathoms).

Occurrence in San Diego Fm. — L.A.M. Loc. 305.

Description. — No original description. Diagnostic characters given by Turner, 1954, are: Shell usually found boring into *Haliotis* or other shells; occasional specimens are found in clay and soft stone. Umbonal reflections broad and closely appressed for their entire length. Mesoplax truncate posteriorly, pointed anteriorly and lacking lateral wings. Siphonoplax heavy, not diverging and composed of a chitinous outer layer which is lined with a white, granular, calcareous deposit.

Remarks. — Two small, oval, nearly smooth valves of *Penitella conradi* in the present collections were in a hole bored in a fragment of a shell (possibly a pectenoid). Dr. Ruth Turner kindly verified the identification of the species. A large specimen from Loc. 305C, the mesoplax

lacking, the interior filled with soft sandy silt, is 25 mm long, 20.3 mm high, convexity (both valves together), 19.2 mm. The shell characters of this specimen agree well with those shown in Turner's illustrations of *P. conradi* as well as with those of Recent specimens identified as that species in the collections of the California Academy of Sciences.

Specimens of *Penitella conradi* are similar to those of juvenile *P. penita* but can be separated from the latter by the shorter, more rounded posterior slope and by the shorter, more sharply upturned concentric ridges on the anterior portion of the shell.

Turner (1955) gave a thorough discussion and good illustrations of *P. conradi.* Large Recent specimens were reported by her to be 33 mm long and 16.5 mm high. She included *Martesia intercalata* Carpenter (1310) from Mazatlan, Mexico, in the synonymy but that locality was not included in the range given for *P. conradi.*

Smith (1311) recently discussed the morphology of *P. conradi* relative to its ability to penetrate shell material.

Penitella penita Conrad
Plate 56, Figures 8, 9, 16; Plate 57, Figures 1, 2

P[holas]. penita Conrad, Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 237, pl. 18, fig. 7, 1837.

Pholas concamerata Deshayes, Rev. Zool., Soc. Cuviérienne, [Vol. 2] p. 357, Ann. 1839. "Californie, dans les marnes calcaires des rivages." — Deshayes, Mag. de Zool., Guérin-Méneville, Ser. 2, Vol. 2, pl. 17, 1840.

Penitella spelaeum Conrad, House Doc. 129, Projected Vol. 3, 33rd Congress, 1st Session, 1855. App. to Prelim. Geol. Rept. of W. P. Blake, p. 16. "Locality.—San Pedro. Recent formation." — Conrad, U. S. Pacific Railroad Expl., Vol. 5, Pt. 2, Art. 2, pp. 319, 326, pl. 5, figs. 43, 43a, 43b, 1857 (as *P. spelaea*). Locality same as in preceding reference.

Penitella curvata Tryon, Amer. Jour. Conch., Vol. 1, Pt. 1, p. 40, pl. 2, figs. 6, 7, 8, February 25, 1865. "Habitat, Straits of Fuca."

Pholadidea sagitta (Stearns MS.), Dall, Proc. U. S. Nat. Mus., Vol. 52, No. 2183, p. 417, December 27, 1916. "The type-specimen comes from Monterey, California." [A young specimen according to Turner, 1954.]

Pholadidea penita Conrad, I. S. Oldroyd, Stanford Univ. Publ. Ser. Geol. Sci., Vol. 1, p. 211, pl. 21, fig. 10 (copy of Conrad's original figure); pl. 51, figs. 3a, 3b, 1924. "Range. Chirikoff Islands, Alaska, to San Pedro, California."

Penitella penita Conrad, Fitch, State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 97, fig. 63, 1953. "Range: Chirikoff Island, Alaska, to Turtle Bay, Baja California."—Turner, Johnsonia, Vol. 3, No. 34, p. 80, pls. 5 (fig. No. 33), 47-51, 1955. Bering Island, Siberia, to Bahía Bartolomé (Turtle Bay), Lower California. — Evans, Proc. Malacol. Soc. London, Vol. 38, Pt. 2, pp. 111-119, pls. 1-4, figs. 1-6 in text, August, 1968. Oregon, Recent.

Type specimen. — Location unknown to the present authors.

Type locality. — "Inhabits with the preceding". [That is, *P. californica* and *Cypricardia californica* which "Inhabits soft argillaceous rocks, which are bare at low water, with the Pholades, in the vicinity of Sta. Diego and Sta. Barbara."]

Range. — Middle Miocene (Topanga Formation) to Recent. Recent from Bering Island, Siberia, to Point Abreojos (1312), Lower California, Mexico, in intertidal zone, in cavities excavated in clay, hard rock, or cement. Dredged at the depth of 79 meters (43 fathoms).

Occurrence in San Diego Fm. — S.D. Loc. 417. Loc. 312 [= 417 (SD)].

Original description. — Shell ovate, elongated, contacted submedially and grooved; anterior side inflated, with decussating lines, the radiating striae having a granulated appearance, posterior side subcuneiform, extremity truncated, with a membranous expansion or appendage; apophysis oblique, slender, spoon shaped at the extremity. (Conrad.)

Remarks. — One right and three left valves are present in the collections from San Diego studied by us. These are single valves, imperfectly preserved, the largest is 52 mm long, 28.6 mm high, convexity, 14 mm. Large Recent specimens attain a length of 92 mm.

The accessory plates are lacking on the fossils in the present collections and identification of the species is based upon other shell characters. The shape of the mesoplax, when present, pointed posteriorly, easily serves to separate this species from similar ones. The broad, closely appressed umbonal reflection on the present specimens is characteristic of *Penitella penita* in comparison to the narrower, higher reflection present on *P. gabbi* Tryon and *Chaceia ovoidea* Gould. The shell of *P. penita* attains a much greater size than that of *P. conradi* Valenciennes which rarely exceeds 33 mm in length. The mesoplax of *P. conradi* is truncated posteriorly rather than pointed. The callum of adult specimens of *P. penita* is complete, that of *P. fitchi* is not complete but has a pedal gape, that of *P. gabbi* does not cover the extreme anterior end of the valves. All these west American species have been discussed and illustrated by Turner. The shape of the shell of *P. penita* is variable and may be a result of crowding or to the hardness of the substrate (Evans, 1968).

Penitella penita has not been recorded with certainty as occurring earlier than in beds of middle Miocene (1313) age. A fossil was cited as "*Pholadidea* aff. *penita* Conrad" by Clark (1314) from beds of Oligocene age southwest of Walnut Creek, California, but the state of preservation precluded positive identification. The same author later described a species from the same area under the name of *Pholadidea (Penitella) lorenzana* (1315). This fossil form was described as differing from *P. penita* in the much greater size, wider mesoplax which is pointed at the anterior end and the upper surface flat rather than concave.

Penitella turnerae Evans and Fisher (1316) described from Coos Bay, Oregon, differs from *P. penita* by its lack of a siphonoplax and by its larger size. Furthermore, the mesoplax, posteriorly, is narrowly crescentic whereas that of *P. penita* is sharply pointed and that of *P. gabbi* is acutely rounded.

A species in Japan, formerly referred to *P. penita*, was renamed *P. chishimana* by Habe (1317). The oriental species is said to differ from the California form in that the posterior end is not truncated and the growth lines are undulated. Records of Recent and perhaps fossil (1318) forms from Japan and possibly some from the north Pa-

cific cited under the name of *P. penita* may be referable to *P. chishimana* or other species.

FAMILY TEREDINIDAE RAFINESQUE (1319)

Much has been written concerning members of the family Teredinidae because of damage resulting from their habit of boring wood thus wreaking destruction upon wooden ships, pilings, or other structures.

A recent illustrated catalogue of the Teredinidae by Turner (1320) is indispensible to anyone working with this group of organisms.

["*Xylotrya*" sp.]

"*Xylotrya*, sp. indet. Tube only.", Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 296, 1874. "well at San Diego," Pliocene. — Orcutt, West Amer. Sci., Vol. 6, Whole No. 46, p. 85, 1889. Dall's record (1874) cited. — Orcutt, quoted by Ellis in Ellis and Lee, U. S. G. S., Water Supply Paper 446, p. 59, 1919. Dall's record (1874) cited. — Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 48, 1944. Dall's record (1874) cited.

Specimen. — Probably lost in the earthquake and fire of 1906.

Occurrence in the San Diego Formation.—San Diego well (Dall).

Remarks. — The sole record, repeated by later authors, of "*Xlotrya*, sp." from the San Diego well, is that of Dall in 1874. No further information is available concerning the tube upon which this record was based.

Xylotrya Leach of authors *(non* Leach in Menke, 1830), was referred to the genus *Bankia* Gray by Clench and Turner (1946, p. 8). The type species of *Bankia* is *Teredo bipalmulata* Lamarck.

A paper by Clench and Turner (1321) contains an excellent discussion accompanied by many pertinent references dealing with the members of the genus *Bankia* in the western Atlantic.

Xylotrya Leach in Menke, 1830, was placed by Turner 1955, in the synonymy of *Xylophaga* Turton, family Pholadidae subfamily Xylophaginae.

Under the current rules of the International Commission on Zoological Nomenclature *Xylophaga* Turton 1822 (1322), type, *X. dorsalis* Turton, is not preoccupied by *Xylophagus* Meuschen, 1788, and the name *Xylotomea* Dall, 1898 (1323) suggested as a possible substitue, is not needed because Meuschen's work has been rejected for nomenclatural purposes by the Internat. Comm. Zool. Nomencl., Opinion 260.

It seems possible that the fossil tube from the San Diego well may be referable to one of the genera of Teredinidae now occurring in west American waters. Any further remarks concerning it at the present time would be sheer speculation.

SUBCLASS ANOMALODESMATA DALL (1324)
ORDER EUDESMONTIDA COX (1325)

SUPERFAMILY PANDORACEA RAFINESQUE (1326)

Shell usually of medium size, thin, with a nacreous inner layer (except Thraciidae), with or without a periostracum; right valve flat, the left convex; hinge with chondrophore and buttresses, sometimes with a lithodesma; pallial sinus lacking in some families, present in others. Late Triassic to Recent.

FAMILY PANDORIDAE RAFINESQUE (1327)

Shell compressed, inequivalve, free, solid, with nacreous and prismatic layers; the dorsal edges of the valves overlapping but not socketed, with dentiform crural ridges on either side of the resilium, but no true teeth; ligament amphidetic, external, obsolete; resilium internal, opisthodetic, usually reinforced on its anterior surface by a medial elongate lithodesma; area none; valves closed, beaks entire, pallial line simple. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 3, p. 532, 1895). Eocene to Recent.

A pallial sinus is lacking in this group. The pallial line is marked by a fine line of small scars extending in an arc between the two adductor impressions.

GENUS *PANDORA* HWASS

Pandora Hwass in Chemnitz, Neues Syst. Conchyl. - Cab., Bd. 11, p. 211, 1795. *Tellina inaequivalvis* and *T. crystallina* cited. — Bruguière, Encycl. Méthod., Vers Testaces, Vol. 2, pl. 250, figs. 1a-c, 1797. (Genus name only.) — Lamarck, Mém. Soc. Hist. Nat. Paris, An VII, p. 88, 1799. Sole species, *Tellina inaequivalvis* Linnaeus. — Boss and Merrill, Johnsonia, Vol. 4, No. 44, p. 189, 1965. "type species my monotypy, Lamarck, 1799, *Tellina inaequivalvis* (Linnaeus)."

Calpodium Röding in Bolten, Mus. Bolt., p. 166, 1798. For *C. albidum* Bolten, in synonymy of which was included *Tellina inaequivalvis* with reference to Chemnitz, Conchyl. -Cab., Vol. 6, pl. 11, figs. 106, a, b, c, d. [*=Tellina inaequivalvis* Gmelin.] — Winckworth, Jour. Conch., Vol. 20, No. 2, p. 52, 1934.

Type species (designated by Children, Quart. Jour. Sci., Vol. 14, p. 302, January, 1823). — "*P. rostrata (Tellina inequivalvis.* Linn.)" [= *Solen inaequivalvis* Linnaeus, Syst. Nat., ed. 10, p. 673, 1758. "Habitat in M. Mediterraneo." Also illustrated by Hanley, Ipsa Linnaei Conchylia, pl. 1, fig. 6, 1855. — Sowerby, Reeve's Conch. Icon., Vol. 19, *Pandora*, sp. 2, pl. 1, figs. 2a, 2b, 1874. "Hab. Great Britain." See Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, p. 46, 1952. — Allen, M. F., and Allen, J. A., discussed the habits of this species (Proc. Malacol. Soc. London, Vol. 31, Pts. 5 and 6, pp. 175-185, figs. 1-5 in text, December 30, 1955.]

Range. — Eocene to Recent in Europe; late Oligocene (San Ramon) or early Miocene to Recent in North America. Recent from the littoral zone to 1902 meters (1040 fathoms).

Description. — Shell inequivalve, thin, pearly inside; valves close, attenuated, behind; right valve flat, with a

diverging ridge and cartilage-furrows; left valve convex, with two diverging grooves at the hinge; usually no ossicle; pallial line slightly sinuated. Outer layer of regular vertical, prismatic cells. (Tryon, G. W., Jr., Structural and Systematic Conchology, Vol. 3, p. 143, 1884.)

Remarks. — Three species of *Pandora* have been recorded occurring in strata of Pliocene age in California, one of which occurs in the San Diego Formation.

Recent members of this genus are world wide in distribution but they are most abundant in cold or cool temperate waters. Eight species have been recorded as occurring at the present time in marine waters between the Bering Sea and San Diego, California. The extreme range in depth cited for these species is 5 to 369 meters (3 to 202 fathoms), but the average depth appears to be about 46 to 91 or 137 meters (25 to 50 or 75 fathoms). About a dozen species are living in tropical and subtropical west American waters.

A recent paper by Boss and Merrill (1328) deals with the members of the Pandoridae in the western Atlantic and a catalogue of this family was published recently by the former author (1329)

Key to Subgenera of *Pandora* (1330)

A. Right valve with 2 teeth or crural laminae.
  a. Lithodesma present; right valve with radial markings . . . . . *Pandorella*
  aa; Lithodesma lacking; right valve smooth or with growth lines only . . . . . *Pandora s. s.* (1331)

B. Right valve with 3 teeth or crural laminae; lithodesma present . . . . . *Heteroclidus*

SUBGENUS *PANDORELLA* CONRAD

Pandorella Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 14, p. 572, 1862 (issued February 17, 1863). Sole species, "*P. (Pandora) arenosa*, C [onrad]." — Vokes, Jour. Paleo., Vol. 30, No. 3,p. 763, 1956. — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 76, 1958. — Boss and Merrill, Johnsonia, Vol. 4, No. 4, p. 199, 1965.

Kennerlia Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, pp. 602, 638, August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 88, 124, 1872. — Stoliczka, Mem. Geol. Surv. India, Palaeont. Indica, Ser. 6, Vol. 3, pp. XVI, 61, 1871. "*Pand. (Kenn.) bicarinata*, Carpenter, is the type of the sub-genus."

Type species (by monotypy). — *Pandora arenosa* Conrad [Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, p. 130, 1834. "Locality. Yorktown, Va." Miocene. See also Gardner, U. S. G. S., Prof. Paper 199-A, p. 45, pl. 10, figs. 16, 19, 20, 1948 (as *Pandora (Kennerlia) arenosa* Conrad). See also Boss and Merrill, 1965, p. 200, pl. 122, figs. 1, 2; pl. 125, fig. 3.]

Range. — Miocene to Recent.

Description. — Like *Pandora, s. s.*, but with a lithodesma; right valve with fine but widely spaced and somewhat irregular radial striae. (Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 260, 1931, for *Kennerlia* Carpenter.)

Remarks. — Adequate reasons for replacing *Kennerlia* by the earlier *Pandorella* were given by both Vokes and by K. V. W. Palmer.

Dall, 1921, listed seven species and subspecies of this subgenus living in the eastern Pacific between Bering Sea and San Diego, California, and three or four species have been reported in the Panamic fauna. Four Recent species were reported from the western Atlantic by Boss and Merrill.

Pandora (Pandorella) bilirata Conrad
Plate 47, Figure 1; Plate 48, Figures 14, 17, 18

Pandora bilirata Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 7, No. 7, p. 267, May 1855. — Conrad, U. S. Pacific Railroad Expl., Vol. 6, Pt. II, Geol. Rept., No. 2, p. 73, pl. 5, fig. 25, 1857. "Santa Barbara, Cal." [Probably Pleistocene according to Keen and Bentson, Geol. Soc. Amer., Spec. Papers No. 56, p. 80, 1944.] — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 89, pl. 53, figs. 8, 9, 1924 (under subgenus "*Kennerlyia*"). "Range. Forrester Island, Alaska, to Point Abreojos, Lower California." Recent. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 261, 1931. Various localities, Pleistocene and Recent.

Type specimen. — Location of the type specimen not known to the present authors.

Type locality. — "Locality. — Occurs with the preceding" [which is *Cemoria crucibuliformis* Conrad from "Locality, California. Dr. Heermann."]

Range. — Middle Pliocene to Recent. Recent from Drier Bay, Prince William Sound, Alaska, to Point Abreojos, Lower California, in 18 to 260 meters (10 to 142 fathoms).

Occurrence in San Diego Fm. — L.A.M. Loc. 305.

Original description. — Oblong, very inequilateral, contracted anteriorly, convex medially; posterior side with two distant carinated lines towards the hinge margin which is straight and not oblique; posterior extremity truncated. (Conrad.)

Remarks.—One right valve and two (one a fragment) left valves of *Pandora bilirata* are present in the collection from Loc. 305 (LAM). The larger valve is 13 mm long. This is the first record of the occurrence of this species in the San Diego Formation. Faustman (1332) reported it from the Rio Dell Formation, of middle Pliocene age, in Humboldt Co., northern California.

A similar species, *Pandora pseudobilirata* Nomura and Hatai (1333), occurs in Japanese waters. This Japanese form was described as differing from *P. bilirata* in the less prominent submarginal ridges on the posterior area.

SUBGENUS *HETEROCLIDUS* DALL

Heteroclidus Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1518, October, 1903.

Type species (by original designation). — "Type

Clidiophora punctata Conrad."

Range. — Miocene (1334) to Recent.

Original description. — Like *Clidiophora*, but the long left posterior lamina absent, the right posterior lamina short, and the low anterior right lamina produced; both the anterior laminae end in front of the anterior adductor scar; lithodesma present. (Dall.)

Pandora (Heteroclidus) punctata Conrad
Plate 42, Figures 2, 3, 9, 10

P[andora]. punctata Conrad. Jour. Acad. Nat. Sci. Philadelphia, Vol. 7, Pt. 2, p. 228, pl. 17, fig. 1, 1837. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 90, pl. 53, figs. 6, 7, 1924. Specimens illustrated from San Diego, California, Recent. — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 262, pl. 13, figs. 2a, 2b, 1931. Specimen illustrated from "upper San Pedro (Palos Verdes), upper Pleistocene of San Pedro." Also earlier records cited, ?Miocene to Recent.—Woodring, in Woodring and Bramlette, U.S.G.S., Prof. Paper 222, p. 91, pl. 17, fig. 13, 1950. Graciosa Member of Careaga Santsone; "cf." in Cebada Member, Santa Maria district, California, Pliocene. — Morris, A Field Guide to Shells of the Pacific Coast and Hawaii (Houghton Mifflin Company: Boston), pp. 25, 61, pl. 8, fig. 11, 1952. Vancouver Island to the Gulf of California, Recent.

Clidiophora punctata Conrad, Arnold, Smithson. Misc. Coll. (Quarterly Issue), Vol. 50, Pt. 4, pp. 4, 27, pl. 56, figs. 2, 3, 1907. "Graciosa Ridge, near Orcutt," California, Pliocene. — J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 171, p. 181 (type error, as *Clidiophora puctata*), 1912. "San Diego-Purisima," Pliocene.

Pandora (Heteroclidus) punctata Conrad, Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 226, fig. 574, 1958. British Columbia to the Gulf of California, Recent.

Type specimen.—British Museum (Natural History). "1 valve, probably figured holotype" (A. M. Keen, Veliger, Vol. 8, No. 3, p. 172, 1966).

Type locality. — "Inhabits in the neighborhood of Sta. Barbara. Single valves occur on the beach at the recess of the tide."

Range. — Middle Pliocene to Recent. Recent from Vancouver Island, British Columbia, to Cape San Lucas, Lower California. (Keen.) From below low tide to a depth of 46 meters (25 fathoms).

Occurrence in San Diego Fm. — C.A.S. Loc. 957, 1178, 1400. L.A.M. Loc. 305C. S.D. Loc. 21. U.C.L.A. Loc. 1386.

Original description. — Shell much compressed; posterior side produced, extremity rostrated, truncated; ligament margin recurved, sub-margin carinated; within punctate; cardinal teeth three in the superior valve; in the inferior, one elongated oblique tooth. Length, one and a half inches. [Length refers to the largest specimen (footnote).] (Conrad.)

Remarks. — Several excellently-preserved specimens of this species are present in collections from the upper part of the Pliocene section at Pacific Beach. The largest specimen from Loc. 1178 (CAS) is 43 mm long, 23.5 mm high (ventral margin slightly imperfect), the convexity (both valves together), 5.9 mm. Another specimen from Loc. 21 (SD), is 41.2 mm long, 24.6 mm high, convexity (both valves together), 7.6 mm. One of the largest Recent specimens in the collection of the California Academy of Sciences, from Coronado Beach, California, is 45.5 mm long. The fossils agree in all observable characters with Recent specimens of *Pandora punctata* from San Diego. This species also has been recorded from various localities in southern California in beds of Pliocene and Pleistocene age.

The form of *P. punctata* described as "var. *Gabbi* Dall" (1335) from beds of supposed Miocene age was said to differ from *P. punctata* in that it lacks the interior punctations characteristic of the typical form. Woodring (1950) mentioned that rarely Recent shells have no punctae.

FAMILY PERIPLOMATIDAE DALL (1336)

Shell subnacreous, conspicuously inequivalve, nearly closed, edentulous; the resilium internal, between two anteriorly or vertically directed chondrophores, often buttressed, the lithodesma rarely wanting; ligament and area absent; the beaks fissured, the pallial sinus broad and shallow; monoecious; marine. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 3, p. 531, 1895.) Late Cretaceous to Recent.

Lamy (1337) published a paper dealing with many of the Recent species of this family, and three new generic names in the Periplomatidae of Australia were proposed by Iredale (1338). Rosewater (Amer. Malacol. Union, Ann. Repts. for 1968, pp. 37-39) recently presented an outline of the classification of this family.

GENUS *PERIPLOMA* SCHUMACHER

Periploma Schumacher, Essai Nouv. Syst. Habit. Vers Test. pp. 115, 116, 1817. Sole species, *Periploma inaequivalvis* Schumacher. — Dall, Bull. Mus. Comp. Zool., Vol. 12, No. 6, p. 305, 1886. Type *P. inaequivalvis* Schumacher. — Lamy, Jour. de Conchyl., Vol. 75, No. 4, p. 303, 1931. "Qui a pour type *P. inaequivalvis* Schum. = *Anatina trapezoides* Lk. = *Corbula margaritacea* Lk."

Type species (by monotypy). — *Periploma inaequivalvis* Schumacher, 1817, pp. 115, 116, pl. 5, fig. 1. [For references to this species see Lamy, 1931, pp. 304-305.]

Range. — Late Cretaceous to Recent, mostly in warmer waters. Recent in from 7 to 2295 meters (4 to 1255 fathoms).

Description. — Shell suborbicular to elongate-ovate, beaks opisthogyrate, the posterior side typically narrower and shorter. Distinguishing character of the genus is the large chondrophore found in each valve, strengthened below and behind by a rib or clavicle soldered to the wall of the shell. Lithodesma, as described above, is seen only in specimens with tightly closed valves. Surface minutely

granulose, most heavily so on the posterior slope, often faint or absent elsewhere. Surface with plain sculpture of growth lines, or with concentric undulations as in *Cyathodonta*, or strongly radially ribbed. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 460, 1961.)

Remarks.—Seven species of *Periploma* have been recorded from strata of Tertiary age in California. About the same number of species now live in west American waters between Monterey Bay, California, and Peru, only two ranging into California waters.

Key to Species of *Periploma*

A. Beaks nearly centrally located . . . . . *stenopa*

B. Beaks decidedly nearer the anterior end . *planiuscula*

Periploma cf. *P. planiuscula* Sowerby

The following references to the literature, type specimen, type locality, range and description, refer to typical *P. planiuscula.*

Periploma planiuscula Sowerby, Proc. Zool. Soc. London, for 1834, p. 87, issued October 25, 1834. — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 82, pl. 22, fig. 1, 1924. "San Pedro, California, to Guayaquil, Ecuador. In the Pleistocene at San Pedro and San Diego, California." —Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 225, pl. 13, figs. 1a, 1b, 1931. Pliocene to Recent. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press), p. 229, fig. 585, 1958 (as *Periploma planiusculum*). "Southern California to Peru, from the extreme low tide level to depths of a few fathoms."

Periploma (Periploma) planiuscula Sowerby, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 463, pl. 82, figs. 2, 2a-e, 1961. Southern California to northern Peru.

Type specimen. — Location unknown to the present authors.

Type locality. — "Hab. ad Sanctam Elenam." Ecuador.

Range. — Middle Pliocene to Recent. Recent from San Pedro, California, to Negritos, Peru, from extreme low tide to a few meters.

Occurrence in San Diego Fm. — L.A.M. Loc. 305.

Original description. — Per. testâ oblongâ, planiusculâ, inaequivalvi, albicante, impolitâ, tenuiusculâ; latere antico brevi, subrugoso; marginibus, antica subdeclivi subtruncatâ, dorsali rectiusculâ; epidermide tenui, pallescente: long., 2.4, lat. 0.8, alt. 1.8 poll. (Sowerby.)

Remarks. — Several fragments of a *Perpiloma*, the largest about 13 mm long, revealing only the hinge area retaining the chondrophore, are present in the collection from Locs. 305 and 305A (LAM). These agree so well with the corresponding portions of *Periploma planiuscula* Sowerby that we refer them, provisionally, to that species. Sowerby's species is well known in the Pliocene and Pleistocene of southern California and has been reported from strata of Pliocene age in Cosa Rica, Panama, and Ecuador. Recent specimens 47 mm long and 29 mm high have been reported from Costa Rica (see Min. Conch. Club South. Calif. No. 190, p. 21, 1959).

Periploma sanctaecrucis Arnold (1339), a species of late Miocene or Pliocene age, is a possible precursor of *P. planiuscula.*

Periploma teevani Hertlein and Strong (1340) is similar to *P. planiuscula* but the shell is higher in proportion to the length. Furthermore, the rows of pustules on the exterior of the valves are arranged in radial rows rather than the irregular arrangement on *P. planiuscula.*

Periploma venezuelana wiedenmayeri H. K. Hodson (1341) with irregular arrangement of pustules is a Venezuelan Miocene subspecies similar to *P. planiuscula.*

Periploma stenopa Woodring
Plate 41, Figures 6, 7

Periploma cryphia stenopa Woodring, U. S. G. S., Prof. Paper 190, p. 57, pl. 9, fig. 7, 1938.

Type specimen. — No. 496106, United States National Museum.

Type locality. — "Union Oil Co. Hellman No. 18 Dominguez field, depth 4,076 feet (U. S. G. S. locality 13899)". Repetto Formation, early Pliocene.

Range. — Early Pliocene (Repetto Formation) to middle Pliocene.

Occurrence in San Diego Fm. — L.A.M. Loc. 305A.

Original description. — Larger and more elongate than *cryphia* proper and having a more pointed posterior end. Length 45.2 millimeters, height 33.9 millimeters (holotype). (Woodring.)

Remarks. — Four specimens of a *Periploma*, varying in the degree of preservation, are present in the collection from Loc. 305A (LAM) near the Mexican boundary.

The best preserved of these, apparently slightly flattened and the anterior dorsal margin imperfect, is 55.5 mm long, 49.3 mm high, and the convexity (both valves together), 16.5 mm. The shape and shell characters of the four specimens agree so well with the original description and illustration of "*Periploma cryphia stenopa*" Woodring that we identify them with that form which we consider to be a distinct species.

The outline of this species is ovately elongate, the shell is thin, the beaks nearly centrally located along the dorsal margin are fissured as is often the case with fossil specimens of this genus. The anterior end and ventral margin are rounded. The posterior dorsal margin is nearly straight and merges into the obliquely rounded posterior end. A slightly depressed but distinct posterior dorsal area is present. Sculpture consists of fine concentric lines of growth.

One specimen is 56.5 mm long, 39.4 mm high, the convexity (both valves together) 16.4 mm. Another one is 40.6 mm high, the convexity (both valves together) 20 mm.

The present species differs from *Periploma cryphia* Woodring (1342) in the more obliquely rounded posterior end and apparently in the larger flattened posterior area. None of the elongate species of *Periploma* living along the Pacific coast have the beaks as centrally placed as on this

fossil form.

Cochlodesma leana floridana Mansfield (1343), a species of late Miocene age in Florida, 58 mm long, has a more steeply sloping posterior dorsal margin and a less flattened posterior area than that of *P. stenopa.*

The elongate shape and nearly centrally placed beaks of the present species in general are similar to those characters on some species of the genus *Cochlodesma* Couthouy (1344). That genus has a broad, blunt buttress to the chondrophore and below it a very thin supplementary one. This is different from the long thin buttress which Woodring stated is present on *P. cryphia.* Until the character of the buttress of *P. stenopa* is known to be referable to some genus other than *Periploma*, it seems best to leave it in the genus under which it was originally described.

FAMILY THRACIIDAE STOLICZKA (1345)

Shell earthy and cellulo-crystalline, not nacreous; inequivalve, thin, edentulous, often with a granular surface; ligament and resilium chiefly external, opisthodetic, parivincular, seated on posteriorly directed nymphae; area none, beaks usually entire; nearly closed valves, pallial sinus present. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 3, p. 531, 1895.) Jurassic to Recent.

Remarks. — The members of this family occur at the present time in all seas. Some nestle in holes in rocks or in other available cavities whereas others occur on mud to depths of 3600 meters (1968 fathoms), but usually in shallower water.

A paper by Lamy (1346) deals with the Recent species of Thraciidae in the Natural History Museum in Paris and a paper by Soot-Ryen (1347) contains a good discussion of the north European species in this family. A paper by Allen (1348) contains the results of a careful study of the British species of *Thracia.*

Key to Genera of Thraciidae

A. Shell ornamented by prominent oblique concentric undulations; granulose . . . . . *Cyathodonta*

B. Shell ornamented only by fine concentric lines of growth; often with fine granulation; texture often earthy . . . *Thracia*

GENUS *THRACIA* LEACH

Thracia Leach in Sowerby, Min. Conch., Vol. 5, No. 72, p. 20, July 1, 1823. [No species cited.] — Blainville, Dict. Sci. Nat., Vol. 32, p. 347, 1824. Species cited: division "A" with "*Thracia corbuloidea*" and division "B" with "*T. pubescens* Leach *Mya pubescens.* Linn." — Arkell, Palaeontogr. Soc. London, Vol. 89, British Corrall, Lamell., Pt. IX, p. 354, 1936. "Type: *Mya pubescens.* Linné." — Vokes, Jour. Paelo., Vol. 30, No. 3, p. 763, 1956.

Type species (designated by Anton, Verzeichniss der Conchylien, p. 2, 1839). — *Thracia "pubescens* Lam." [= *Mya pubescens* Pultenye, Cat. Birds, . . . Shells, . . . Plants, . . . Doresetshire, ed. 1, p. 27, 1799. "Dredged up at Waymouth" [Weymouth]. For synonymy and references to this species see Lamy, Jour. de Conchyl., Vol. 75, No. 3, pp. 217-220, 1931. England to the Mediterranean, Senegal, and Canary Islands. Good illustrations of this species were published by Soot-Ryen, Tromsø Mus. Arshefter (Naturhist. Avd. Nr. 17), Vol. 61, No. 1, pl. 5, figs. 1, 2; pl. 7, fig. 4; pl. 9, fig. 8 a-c, 1941.]

Range. — Typical *Thracia,* Eocene to Recent and perhaps Triassic to Recent. Recent in from 5 to 3600 meters (3 to 1968 fathoms).

Description. — Shell concentrically striated, with more or less fine superficial granulation and a very delicate periostracum; subrostrate, slightly gaping behind; slightly inequivalve, the right valve larger; the beaks in contact and usually perforated by friction on each other,the hinge-plate fissured below them and edentulous; the ligament external, the resilium more or less sunken and with, in most cases, a short, transverse lithodesma in front of it, occupying the fissure in the hinge-plate; pallial line with a moderate sinus, margins of the valves entire; the nymphs in the typical forms do not project greatly from the hinge-margin ventrally and more or less elongated; the shell is destitue of nacre. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1523, 1903.)

Remarks. — Blainville was the first author to assign species to the genus *Thracia* in 1824. He proposed two divisions, "A" with a chondrophore in one valve, represented by *T. corbuloidea*, and the other "B" with a chondrophore in each valve, represented by *T. pubescens.* Later Blainville (1349) stated that his division "B" should be suppressed because the species which he cited was not correctly identified. This procedure, if valid, would leave *T. corbuloidea* as type of *Thracia*, as stated by Keen (1350). However, under the Internat. Rules Zool. Nomencl., such action by an author has no validity in nomenclature.

Anton, 1839, designated *Thracia pubescens* "Lam." as type species of *Thracia.* Although he attributed this species to Lamarck, rather than to Pulteney, his designation of type species is the earliest for this genus. Deshayes (1351), 1830, evidently considered this same species (attributing it to Linnaeus) to be the type of *Thracia* but he did not definitely so designate it.

Four species of *Thracia* have been recorded from strata of Pliocene age in western North America and a new species here described occurs in the San Diego Formation. About an equal number have been described from pre-Pliocene strata in the same region. Eight species have been reported living in west American waters between the Bering Sea and northern Peru.

A paper by Kamada (1352) dealing with the Tertiary species of *Thracia* in Japan appeared recently. Some of these Oriental species are similar to west American Tertiary forms.

Thracia kanakoffi n. sp.
Plate 42, Figures 11, 13, 14, 15

Description. — Shell large, thin, valves slightly

unequal, nearly equilateral, moderately convex; anterior margin sloping rather steeply and rounding into the broadly rounded base, the posterior dorsal margin sloping very gently downward to the slightly rounded truncated posterior end; a well-developed umbonal ridge delimits the posterior end; anterior to this is a well developed radial depression on the right valve but on the left valve a corresponding depression is much less developed; a narrow but distinct ridge is present just below and diverging slightly from the posterior dorsal margin on the right valve; sculpture consisting of incremental lines of growth, a few slight concentric furrows on the umbos, and over most of the shell especially toward the base, granulations are rudely concentrically arranged except toward the ventral margin where they may assume a rude radial arrangement; on the posterior dorsal area the rows of granulations often coalesce to form beaded threads which are rudely concentric but sometimes form interlacing patterns. Dimensions of holotype: length, 81 mm, height, 54.2 mm, convexity (both valves together) 32 mm, beak approximately 39 mm from anterior end.

Type specimen. — Holotype and two paratypes from Loc. 291 (LAM), silt beds exposed in a gully in the center of the south half of Sec. 27, T. 4 N., R. 15 W., San Bernardino Base and Meridian; one half mile south of the Humphrey railroad station, Los Angeles Co., California; Pico Formation, middle Pliocene.

One paratype is 93 mm long, 70.4 mm high, convexity (both valves together) 38 mm. The other in which the hinge of the right valve is exposed is 93 mm long and 68 mm high. On a specimen 96.5 long, the pallial sinus extends anteriorly 39 mm, on another specimen 74 mm long the pallial sinus extends anteriorly 34 mm from the posterior end of the valve.

Occurrence in San Diego Fm. — C.A.S. 1419. L.A.M. 107, 305. S.D. 34.

Remarks.—Over fifty specimens from the type locality have been available for study. These range in length from 5 mm to 96.5 mm. The hinge, where exposed, appears to be that of typical *Thracia.*

This new species bears considerable resemblance to *Thracia trapezoides* Conrad (1353) but it differs in the less steeply sloping posterior dorsal margin, in the presence of a narrow ridge just below and gently diverging from the posterior dorsal margin of the right valve, and in the less developed radial depression just anterior to the posterior umbonal angulation on the valves.

The present form attains a huge size. A cast, somewhat compressed, lacking the shell, from Loc. 107 (LAM) is 132 mm long and 86 mm high.

The largest specimen of *Thracia trapezoides* from Puget Sound in the collection at Stanford University is 67 mm long. The largest specimen of the latter species among a series from the Timm's Point Formation, Loc. 130-7 (LAM), of late Pliocene or early Pleistocene age, is 60.4 mm long. This species is reported living in west American waters from Craig, Alaska, to Redondo Beach, California, in 64 to 173 meters (35 to 75 fathoms), in mud.

Thracia kakumana Yokoyama as illustrated by Kamada (1354) from strata of Pliocene age in Japan attains a length of 80 mm. It bears a resemblance to *T. kanakoffi* n. sp., but the anterior end is more broadly rounded and the surface of the valves is said to lack granulation.

This new species is named for George P. Kanakoff, formerly Curator of Invertebrate Paleontology, Los Angeles County Museum, who made an extensive collection of Pliocene fossils in the San Diego area and who generously made this materal available for the present monograph.

GENUS *CYATHODONTA* CONRAD

Cyathodonta Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 4, p. 155 1849. Sole species, *Cyathodonta undulata* Conrad. — Lamy, Jour. de Conchyl., Vol. 75, No. 3, p. 215, 1931. "Type: *T. undulata* Conr." — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 459, 1961. "Type species by monotypy, *Cyathodonta undulata* Conrad."

Type species (by monotypy). — *Cyathodonta undulata* Conrad [Proc. Acad. Nat. Sci. Philadelphia, Vol. 4, p. 156, 1849. Title of article states, "Shells are from the coasts of Lower California and Peru." "East coast of Lower California," designated as type locality by Hertlein and Strong (Zoolgica, Vol. 31, Pt. 3, No. 8, p. 96, December 5, 1946). Illustrated by Keen, Sea Shells of Tropical West America (Stanford Univ. Press), p. 232, fig. 595 (on p. 233), 1958. Southern part of the Gulf of California to Peru.]

Range. — Oligocene to Recent. Recent in from 22 to 73 meters (12 to 40 fathoms), and perhaps deeper.

Description. — Shell broadly ovate to subrectangular, the anterior side longer, rounded, the posterior side shorter, depressed, and subtruncate; beaks entire, not fissured by contact with each other; cardinal plate not fissured; ligamental myophores short, rounded, projecting with a thin, semicircular lithodesma suspended vertically in front of them. Surface sculptured with strong concentric, sometimes oblique, wave-like plications or undulations; surface granulose. (Adapted from Lamy, 1931 (free translation), and Olsson, 1961.)

Remarks. — The shell of *Cyathodonta* differs from that of *Thracia* in the strong, obliquely concentric corrugations of the valves and in the strongly granulose surface, the granules often arranged in a definite pattern.

The first appearance of this genus in west American Tertiary strata is that of *Cyathodonta weaveri* Clark (1355) in the San Ramon Formation often assigned late Oligocene age, in west central California. Species also have been recorded from beds reported to be of Oligocene age in Mississippi and Porto Rico and in beds of Miocene age in the Caribbean region, in Costa Rica, and in Panama. "*Cyathodonta* sp." has been recorded from beds of late Miocene age (Neroly) in southern California by Eaton, Grant, and Allen (1356). This genus also is present in beds of Pliocene and of Pleistocene age in southern California and in Lower California and in the Pleistocene of Panama.

Five, possibly six, species and subspecies live in west American waters between Monterey, California, and Peru, and the Galápagos Islands. Two of these range north into southern Californian waters.

Cyathodonta sp.

Occurrence in San Diego Fm. — L.A.M. 104, 305.

Remarks. — A species of *Cyathodonta* is represented by several fragments at Loc. 305 (LAM). A fragment of a right valve, 10.8 mm long, retains the hinge area. The chondrophore on this and on other fragments projects downward at an angle of about 45°. In this character as well as in the numerous rather fine concentric corrugations on the umbo, the fragment resembles *Cyathodonta formosa* Nomland (1357) described from upper Etchegoin Pliocene beds in the San Joaquin Valley. The fragmental character of the specimens is such as to preclude positive specific identification.

A portion of a small valve about 10 mm long is exposed in matrix from Loc. 104 (LAM). The corrugated concentric sculpture of the shell is similar to that of *Cyathodonta* but the species represented is open to question.

ORDER POROMYOIDA PELSENEER
SUPERFAMILY POROMYACEA DALL
FAMILY POROMYACIDAE DALL (1358)

Shell small, thin, rounded or cordate, subequilateral, umbos central, prosogyrate, posterior side sometimes angulated, valves closed or nearly so, the interior pearly; exterior with rows of granules or smooth; ligament external, opisthodetic; resilium sub-internal below the ligament, seated upon a chondrophore, a small lithodesma present; hinge of right valve with a stout cardinal tooth behind and above chondrophore in typical genus but teeth nearly obsolete in the adults of some genera; muscle impressions subequal, suborbicular, the posterior one slightly smaller; pallial sinus small or lacking. [Adapted from Dall, Eastman's ed. of Zittle's Textbook of Paleontology, Vol. 1, p. 469, 1913, and Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 466, 1961.] Cretaceous to Recent.

Remarks. — The majority of the members of this family live in deep water, but a few occur no deeper than 55 meters (30 fathoms). These mollusks occur rather rarely as fossils.

Dall (1359) discussed the systematics of this family and mentioned the characters by which various supraspecific units may be separated.

GENUS *DERMATOMYA* DALL

Dermatomya Dall, Bull. Mus. Comp. Zool., Vol. 18, pp. 448 et seq., 452, May 20, 1889. Sole species, *Poromya (Dermatomya) mactroides* Dall. — Dall, Proc. U.S. Nat. Mus., Vol. 12, No. 773, pp. 289, 291, 1889 (issued March 7, 1890). — J. Q. Burch, Min. Conch. Club South. Calif., No. 38, p. 11, August-September, 1944. "Type (by monotypy) *Dermatomya mactroides* Dall 1889. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), pp. 466, 467, 1961.

Type species (by monotypy). — *Poromya (Dermatomya) mactroides* Dall [Bull. Mus. Comp. Zoöl., Vol. 18, p. 448, May 20, 1889. "It was dredged by the Albatross off the coast of Ecuador, in 741 fms." — Dall, Proc. U.S. Nat. Mus., Vol. 12, No. 773, p. 291, pl. 8, fig. 8, 1889, issued March 7, 1890 (as *Dermatomya mactroides*). — Dall, Bull. Mus. Comp. Zool., Vol. 43, No. 6, p. 429, 1908 (as *Poromya (Dermatomya) mactroides).* Type specimen said to be the one illustrated in 1889 (1890). Off southern Chile or western Patagonia in 122, 348, 449 fathoms. See discussion below under Remarks].

Range. — Middle Pliocene to Recent in eastern Pacific and Japan, in 55 to 3058 meters (30 to 1672 fathoms), and perhaps deeper.

Description. — Shell small, subovate, subequilateral, sometimes angulated posteriorly; umbos central, usually somewhat inflated, prosogyrate; exterior sculptured only with concentric lines of growth; hinge of right valve with a stout subumbonal cardinal tooth in front of a rather wide chondrophore; hinge of left valve with a notch which received the cardinal in the opposite valve, a small cardinal tooth behind and above the chondrophore; pallial sinus well developed.

Remarks. — The genus *Dermatomya* is recorded here from the San Diego Formation for the first time. Previously it was reported from beds at Timm's Point, San Pedro, California, believed to be of Pleistocene age. The generally deep water habitat of members of this genus probably explains the paucity of fossil occurrences. Seven species live in the waters of the eastern Pacific between Alaska and Chile and one species or subspecies lives in Japanese waters.

The type species of *Dermatomya*, *Poromya (Dermatomya) mactroides*, was first briefly described by Dall May 20, 1889, and the locality cited off Ecuador in 741 fathoms. The following year a more extensive description and an illustration of the species was published and three localities were mentioned on the west coast of Patagonia and one off Ecuador. The length of the shell in the description and in the illustration was given as 18 mm. In 1908 Dall referred to this species, stated that the type was illustrated in 1889 [1890], that it was 10 mm long, and that it was a Patagonian species. The shell from Ecuador, 18 mm long, was described as a new species, *Poromya (Dermatomya) equatorialis.* In the explanation to the plate the specimen illustrated was indicated as 6.5 mm long rather than 18 mm as given in the description. The illustration is that of a shell on which the posterior end is more truncated and the posterior groove apparently more developed than that shown in the figure by Dall in 1889 [1890]. There is confusion in the records concerning the two species but this does not affect the conception of the genus *Dermatomya* because the shell characters of the two species are referable to the same supraspecific category.

The genus *Poromya* Forbes (1360) differs from *Dermatomya* in that the shell is sculptured with a series of radial rows of fine granules and it lacks a pallial sinus. *Poromya* is much more widely distributed both geologically and geographically than *Dermatomya.* It has been reported from Eocene to Recent. Species referred to this genus have been described which live in western Europe, in the Mediterranean, Atlantic, Caribbean, Antarctic, eastern Pacific, Japan, East Indies, India and East Africa. Lamy (1361) mentioned a number of species, Recent and fossil from various localities. Under the genus *Poromya*, including three subgenera, Odhner (1362) listed 48 taxa, Recent and fossil. Some of these are referable to other

genera.

One species, *Poromya perla* Dall, was described from the Gulf of Panama at a depth of 2323 meters (1270 fathoms).

The species described as *Poromya gabbiana* Anderson and Martin (1363) from beds of early Miocene age in San Luis Obispo County, California, was later assigned to the genus *Solecurtus* Blainville by Keen and Bentson (1364).

Tegland (1365) reported "*Poromya* n. sp." from the Blakeley Formation in western Washington which she believed to be of late Oligocene age. A fossil from the same area was described by Weaver, (1943, p. 121, pl. 25, fig. 23) under the name of *Poromya teglandae* but Addicott (1366) recently assigned that species to the genus *Macoma*.

Abbott (Nautilus, Vol. 65, No. 1, p. 33, 1951) pointed out that a Recent form described as *Poromya oregonensis* by Ridewood in 1903, with illustrations of the gills and internal organs only, and without information concerning the locality from which it came, "probably should be considered a *nomen dubium*".

Dermatomya tenuiconcha Dall
Plate 56, Figures 6, 7, 10, 11, 13

Poromya (Dermatomya) tenuiconcha Dall, Proc. U.S. Nat. Mus., Vol. 45, No. 2002, p. 596, June 11, 1913.
Poromya tenuiconcha Dall, Dall, U.S. Nat. Mus., Bull. 112, p. 27, pl. 3, fig. 10, 1921 (under subgenus *Dermatomya*). "Alaska Peninsula to Coronado Islands, in deep water." — I.S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 95, pl. 54, figs. 24, 25, 26, 1924. Type locality and range same as cited by Dall.

Type specimen. — No. 266865, United States National Museum.

Type locality. — "In deep water off Monterey Bay, California."

Range. — Middle Pliocene to Recent. Recent from Alaska Peninsula to the Coronado Islands, Lower California, Mexico, in 50 to 133 meters (30 to 73 fathoms), one record of 1205 meters (659 fathoms) (see Burch, J.Q. Min. Conch. Club South. Calif., No. 38, p. 11, August-September, 1944; and Smith, A.G., and Gordon, M., Proc. Calif. Acad. Sci., Ser. 4, Vol. 26, No. 8, p. 172, 1948).

Occurrence in San Diego Fm. — L.A.M. Loc. 305.

Original description. — Shell small, thin, olivaceous, the pearly luster showing through the periostracum; equivalve, inequilateral, anterior end shorter, rounded in front; posterior end longer, roundly truncate; beaks prominent, prosocoelous, with a marked but uncircumscribed depression in the lunular region in front of them; interior pearly, brilliant; margins simple, sharp; hinge in the left valve with a small internal resilium seated on an inconscpicuous oblique chondrophore, with a notch immediately in front of it, into which fits a projecting denticle on the corresponding part of the opposite valve. Height, 13; length of shell, 16; anterior portion, 6; diameter, 10 mm. (Dall.)

Remarks. — *Dermatomya tenuiconcha* is reported here from the San Diego Formation for the first time. Two valves, probably paired, are 9.7 mm long, 8.2 mm high, the convexity (both valves together) 6.8 mm. A small specimen, 5.7 mm long, both valves adhering to each other, appears to be a juvenile form of this species.

This species is rather rare in collections of Recent shells and so far as we know it has been reported previously as a fossil only at Timm's Point, San Pedro, California, from strata which Clark (1367) considered to be of Pleistocene age. According to Burch, it is not uncommon in those beds.

The smooth posterior area, lacking a groove or a carina, serves to separate *D. tenuiconcha* from the tropical *D. equatorialis* Dall (1368).

A subspecies, *D. tenuiconcha soyoae* Habe (1369), described from Japanese waters, is more produced posteriorly than are typical forms of the west American shell.

Another form from Japan, *Dermatomya tenuiconcha sagamiensis* Okutani (1370), described as a questionable variety of the North American species, was said to differ from the latter in the "somewhat elongated shell, paler coloration and nearly horizontal chondrophore."

FAMILY CUSPIDARIIDAE DALL (1371)

Shell subequivalve, rostrate, earthy or cellulo-crystalline, rarely with surface granulations; hinge edentulous or with subumbonal desmodont tuberculation, sometimes buttressed; ligament subinternal, anterior to the beaks or obsolete; resilium internal, with a mesial or ventral lithodesma; area amphidetic or obscure; valves closed except at the tip of the rostrum; pallial line simple; the retraction of the siphons usually effected by the contraction of the septum, the latter leaving a scar on the valves resembling a pallial sinus. (Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 3, p. 536, 1895.) Cretaceous to Recent.

Remarks. — The family Cuspidariidae is represented in strata of Tertiary age in California by one genus with five species in the Eocene and two species in the Pliocene. The family is here reported for the first time from the San Diego Formation. In the Recent west American molluscan fauna 12 species, distributed in four supraspecific units, live in the region between the Bering Sea and San Diego, California, and three genera or subgenera containing six or eight species live in the tropical and subtropical waters in the eastern Pacific.

GENUS *CUSPIDARIA* NARDO

Neaera Griffith and Pidgeon, "The Mollusca and Radiata" in the Animal Kingdom arranged in conformity with its organization, by the Baron Cuvier, with supplementary additions to each order by E. Griffith and others (Whittaker and Company: London), Vol. 12, "*Neaera Chinensis*" on legend to pl. 22, fig. 5, on p. 598 as "*Neroea Chinensis*, Gray," plate dated 1833, whole volume issued 1834.
Not *Neaera* Robineau-Desvoidy, 1830. Diptera.
Cuspidaria Nardo, Ann. Sci. Regno Lombardo - Veneto,

Vol. 10, p. 50, 1840; Rev. Zool., p. 30, 1840. — Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3, p. 307, 1930. Type, *Cuspidaria typus* Nardo. — Prashad, Siboga Exped., Pelecypoda, Monogr. 53c, p. 327, 1932. "The genotype is *Cuspidaria cuspidata* (Olivi)." K.V.W. Palmer, Geol. Soc. Amer., Mem. 76, p. 78, 1958. Type by original designation *Cuspidaria typus* Nardo ms. = *Tellina cuspidata* Olivi.

Type species (by original designation, see Internat. Code Zool. Nomen., Art. 30, b). — *Cuspidaria typus* Nardo ms., Adriatic Sea [= *Tellina cuspidata* Olivi. Zoologia Adriatica p. 101, pl. 4, fig. 3 (A, B, C), 1792. Adriatic Sea, Recent. See also Deshayes, Traité Élém. Conchyl., Tom. 1, Pt. 2, p. 192, pl. 12 bis, figs. 6-8, 1843-1850 (as *Neoera cuspidata)* Mediterranean. — Kobelt, Illustr. Conchylienbuch, Bd. 2, p. 322, pl. 93, fig. 15, 1881 (as *Neaera cuspidata*). — Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 29, p. 123, pl. 26, figs. 31-34, 1901. Elveziano; Piacenziano; Astiano. — Dall in Zittel's Text-Book of Paleontology, ed. by Eastman (Macmillan Co.: London), p. 469, fig. 748, 1913. Austria, Miocene].

Range. — Jurassic to Recent. Recent, widely distributed from 26 to 7297 meters (14 to 3990 fathoms).

Description. — Shell small or of medium size, with a well-rounded, convex, anterior side and a narrowly produced posterior end. Hinge without cardinal teeth, the right valve having a strong, posterior, lateral tooth bordered above by a linear socket into which the margin of the left valve fits. Chondrophore is a narrow, spoon-shaped plate placed directly under the beak, directed slightly backward, and similar in both valves. Surface with concentric ribbing. (Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 465, 1961.)

Remarks. — Five species living in west American waters between the Bering Sea and San Diego, California, were reported under *Cuspidaria s.s.* by Dall in 1921. One species lives in deep water off Panama.

Conrad (1372) published a catalogue of the Recent species known to him in 1869. Kuroda (1373) more recently discussed the species of *Cuspidaria* living in Japan. Eleven species have been reported from that area.

SUBGENUS *CARDIOMYA* A. ADAMS

Cardiomya A. Adams, Ann. Mag. Nat. Hist., Ser. 3, Vol. 13, p. 208, March, 1864. — Eames, Philos. Trans. Roy. Soc. London, Ser. B, Biol. Sci., No. 627, Vol. 235, p. 453, 1951. Type by monotypy, *Neaera gouldiana* Hinds.

Type species (by monotypy). — *Cardiomya gouldiana* Hinds [= *Neaera gouldiana* Hinds, Proc. Zool. Soc. London for 1843, p. 77, December, 1843. "Hab. New Guinea; Cagayan, island of Mindanao; and Bay of Manila, Philippines: in from seven to thirty fathoms, sandy mud." — Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, p. 70, pl. 20, fig. 17, 1845. — Chenu, Man. de Conchyl., Vol. 2, p. 50, fig. 208, 1862. — Kobelt, Illustr. Conchylienbuch, Bd. 2, p. 322, pl. 93, fig. 16, 1878].

Range. — Late Cretaceous to Recent. Recent, widespread, in 18 to 4380 meters (10 to 2395 fathoms).

Description. — Shell similar to that of *Cuspidaria s.s.* but with sculpture of radial ribs and larger, more vertically directed chondrophore.

Remarks. — Most of the species described under the genus *Cuspidaria* from strata of Tertiary age in California are referable to the subgenus *Cardiomya.* Ten species have been reported living in the eastern Pacific between the Bering Sea and Ecuador. Six species of this subgenus have been reported from Japanese waters.

Cuspidaria (Cardiomya) pectinata Carpenter
Plate 57, Figure 14

Neaera pectinata Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 602, 637, issued August, 1864. Reprint in Smithsonian Misc. Coll., No. 252, pp. 88, 123, 1872. — Carpenter, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, p. 54, 1865. "Hab. - In sinu Pugetiano junior legit Kennerley." "Apud insulam catalinam et Sanct. Barbaram adultum piscavit Cooper." — Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 181, pl. 18, fig. 11, 1903. Lower San Pedro Series at Deadman Island, San Pedro, California, Pleistocene.

Cuspidaria pectinata Carpenter, I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 101, 1924 (under section *Cardiomya*). Type locality, Puget Sound. Range, Puget Sound to Panama Bay.

Cuspidaria (Cardiomya) pectinata Carpenter, Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 265, pl. 1, figs. 16, 17, 1931. Pleistocene and Recent. — Hertlein and Strong, Zoologica, Vol. 31, Pt. 3, p. 101, 1946. Cedros Island, Lower California. — K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 78, pl. 6, figs. 1-5, 1958. Earlier records cited. — Keen, Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), p. 234, fig. 600, 1958. Puget Sound to Cedros Island, Lower California.

Type specimen. — No. 4506, United States National Museum.

Type locality. —"Puget Sound Washington (type)" (see Palmer, 1958, p. 79).

Range. — Middle Pliocene to Recent. Recent from Puget Sound to Cedros Island, Lower California, in 18 to 82 meters (10 to 45 fathoms). Reported from west of Mazatlan, Sinaloa, Mexico, in 84 to 92 meters (Parker, R. H., Vidensk. Medd. Dansk. Naturh. Foren., Bd. 126, p. 162, 1964).

Occurrence in San Diego Fm. — L.A.M. Loc. 305A.

Original description. — "Principal ribs about 12; beak smooth. Like *sulcata*. 40-60 fm. cp." (Carpenter, 1864.)

Supplementary description. — N. t. globosâ, albidâ, subdiaphanâ; epidermide tenui indutâ; ventraliter antice productâ, postice subito angustato, rostrato; rostro haud insculpto, duabus inter quinque partes toius longitudinis aequante; parte globosâ acute costatâ; costis posticis paullum marjoribus, magis distantibus; margines dorsales versus obsoletis; interstitiis latis, quadratis, minutissime concentrice striatis; costis principalibus t. jun. xii, -xv., adultâ, aliis crebre intercalantibus, circ. xxx., quarum primi majores: intus, laminâ cartilagineâ curtâ, sub umbones celata; dente postico satis elongato, regione adductoris intus claviculato; cicatricibus adductoribus subrotundatis, deorsum

sitis; sinu palii parvo, lato: margine à costis pectinato. Long. .24, lat. .14, alt. .12. (Carpenter, 1865.)

Remarks. — One right valve 7 mm long and 4.2 mm high, is present in the collection of the Los Angeles County Museum from near the Mexican boundary. The valve is quite convex and the main portion is sculptured with about 14 radial ribs which reach the ventral margin. Some of these ribs develop by dichotomy of the major ribs and some as intercalaries.

The convexity and number of ribs agrees with that of Recent specimens of *Cuspidaria (Cardiomya) pectinata* from California. Specimens of this species from Puget Sound are twice as large as those from California but otherwise appear identical.

Cuspidaria (Cardiomya) californica Dall (1374) was described as possessing a smaller, proportionally longer and less inflated shell sculptured with 16 to 20 radial ribs, with a straighter rostrum ornamented with two strong radiating lirae. There is variation in a series of specimens of *C. pectinata* and as mentioned by Palmer, Carpenter called attention to the variability in the number of ribs. The relationship of the two species is now known with certainty.

The shell of *Cuspidaria (Cardiomya) oldroydi* Dall (1375), described from Puget Sound, was said to be larger and more inflated than that of *C. pectinata* but otherwise the two appear to be very similar.

Vedder (1376) recently reported "*Cardiomya* cf. *C. pectinata* (Carpenter)" from sandstone strata of Pliocene age northeast of Newport Beach, California.

Simonova (1377) reported a fossil under the name of *Cuspidaria (Cardiomya) pectinata* Carpenter from strata of late Tertiary age in the southeastern part of Sakhalin Island, but the illustration is not convincing as to the identity.

FAMILY VERTICORDIIDAE STOLICZKA

Shell equivalve, or nearly so, of small size, inflated, with the beaks incurved, closed all around, more or less solid, pearly inside; hinge with few cardinal teeth, more or less obsolete, ligament subinternal or internal; two muscular impressions, pallial line simple. (Tryon, G. W., Jr., Struct. and Syst. Conch., Vol. 3, p. 196, 1884.). Paleocene to Recent.

Remarks. — Members of this family are widely distributed geographically and geologically. They occur as early as Paleocene in some regions but the present record of *Verticordia* in the San Diego Formation is the earliest known in western North America.

Kuroda (1378) discussed the Verticordiidae of Japan and Iredale (1379) proposed a number of genera for species of this family living in Australian waters. Soot-Ryen (1380) recently discussed this family, especially northern members of the group.

GENUS *VERTICORDIA* WOOD

Verticordia J. E. Gray, Synop. Contents Brit. Mus., ed. 42, p. 150, 1840. (*Nomen nudum.* See Iredale, T., Proc. Malacol. Soc. London, Vol. 10, pp. 299, 309, 1913.)
Verticordia S. Wood in Sowerby, Min. Conch. Great Britain, Vol. 7, p. 67, pl. 639, August 1, 1844. Sole species, *Verticordia cardiiformis* J. Sowerby. — S. Wood, Palaeontogr. Soc. (London), Vol. 24, Eocene Moll., Vol. 1, Pt. 4, No. 3, p. 137, 1871. — Dall, Bull. Mus. Comp. Zool., Vol. 12, No. 6, p. 285, 1886. "The type of *Verticordia* as restricted is *V. cardiiformis* Sowerby (Min. Conch., pl. 639, 1844)." — Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 6, p. 1509, 1903. "Type *Cryptodon verticordia* Searles Wood, + *Hippagus cardiiformis* Sowerby." — Prashad, Siboga Exped. Monogr. 53c, Lamell., p. 323, 1932. "The Genotype is *Verticorida cardiiformis* Sowerby."—Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 68, 1953. "Type by monotypy: *Verticordia cardiiformis* Sowerby."—Stenzel, Krause, and Twining, Univ. Texas, Bull. Bur. Econ. Geol., Publ. No. 5704, p. 177, 1957. Type by monotypy.

Type species (by monotypy). — *Verticordia cardiiformis* J. Sowerby (on pl. 639, figs. a, b, c, d) cited as "*Hippagus ? cardiiformis*" on p. 68 (in the synonymy of which is "*Cryptodon Verticordia*, S. V. Wood, Cata. Ann. and Mag. Nat. Hist. v, vi. 247"). "coralline crag of Sutton." [Pliocene.] Illustrated by S. V. Wood, Paleontogr. Soc. (London), Vol. 4, Monogr. Crag Moll., Pt. 2, p. 150, pl. 12 figs. 18a, 18b, 1850 issued June, 1851 (as *Hippagus verticordius*). "Coralline Crag, Sutton." — Tryon, Struct. and Syst. Conch., Vol. 3, p. 197, pl. 125, fig. 26, 1884.]

Range. — Paleocene (1381) to Recent. Widely distributed over the world. Recent in from 9 to 4261 meters (5 to 2330 fathoms).

Description. — Shell generally small, suborbicular, cardiform, equivalve, the beaks strongly prosogyrate above a deep, entering lunular indentation with thickened margins. Shell texture heavy, nacreous within and with a thin, chalky outer layer minutely shagreened. The hinge of the right valve shows a stout, conical cardinal tooth placed behind the lunular indentation; there are no laterals. Ligament internal, supported by a lithodesma. Pallial line simple. Sculpture is formed by strong, radial ribs. [Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 469, 1961.)]

Remarks. — Fischer (1382) discussed the generic units *Verticordia* and *Hippagus* and the species assigned to them.

The genus *Verticordia* is here reported from the San Diego Formation for the first time.

Two species in west American waters have been assigned to *Verticordia s. s.* These are *V. aequicostata* Howard (1383) and *V. perplicata* Dall (1384). One species living in this region is placed in the subgenus *Trigonulina.*

SUBGENUS *TRIGONULINA* D'ORBIGNY

Trigonulina d'Orbigny in Sagra, Hist. Phys. Pol. et Nat. Cuba, Vol. 7, Moll., Vol. 2, p. 291, 1846. Sole species, *Trigonulina ornata* d'Orbigny. — Dall, Bull. Mus. Comp. Zoöl., Vol. 12, No. 6, p. 286, 1886. Type by monotypy. — Woodring, Carnegie Inst. Washington, Publ. 366, p. 92, 1925. Type by monotypy. — Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 68, 1953. Type by monotypy.

Type species (by monotypy). — *Trigonulina ornata* d'Orbigny.

Range. — Eocene to Recent.

Description. — Shell similar to *Verticordia*, but the ribs more irregularly and widely spaced on posterior side. Right valve with a long, posterior lateral socket. (Olsson and Harbison.)

Remarks. — Only one species, the type of this subgenus, has been reported both as a fossil and Recent from the western Americas but a number of species occur in other regions.

Verticordia (Trigonulina) ornata d'Orbigny
Plate 43, Figures 23, 26, 27, 31

Trigonulina ornata d'Orbigny in Sagra, Hist. Phys. Polit. et Nat. Cuba, Vol. 7, Moll., Vol. 2, p. 292, pl. 27, figs. 30, 31, 32, 1853. — Chenu, Man. de Conchyl., Vol. 2, p. 169, fig. 843, 1862.

Verticordia ornata d'Orbigny, Dall, Bull. Mus. Comp. Zool., Vol. 9, No. 2, p. 105, 1881. "Barbados, 100 fms." "Station 19, 310 fms." "Catalina Island, California, 16 fms. Dall; shell sand, Jamaica, W. I., d'Orbigny." [Not the record "China Seas, Adams."] — I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 103, pl. 54, figs. 15, 16, 17, 18, 1924. "Catalina Island, California, to Panama Bay" and "Antilles." [Not the record "Japan."] — Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 266, pl. 13, fig. 4, 1931. Pleistocene and Recent. — McLean, New York Acad. Sci., Surv. Porto Rico and Virgin Islands, Vol. 17, Pt. 1, p. 51, pl. 10, fig. 5, April 11, 1951. "Porto Rico: Mayaguez," Recent.

Verticordia (Trigonulina) ornata d'Orbigny, Dall, Bull. Mus. Comp. Zool., Vol. 12, No. 6, p. 290, 1886. Same localities cited as in 1881. — Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 469, 1961. California to Panama; Caribbean, West Indies to Massachusetts.

Verticordia novemcostata Adams and Reeve, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 126, pl. 17, fig. 10, 1903. "Pleistocene. — San Pedro (Arnold)". Also Recent.

Not *Hippagus novemcostatus*, Adams and Reeve, Voy. Samarang, Moll., p. 76, pl. 24, fig. 1, 1850. "Hab. China Sea."

Type specimen. — British Museum (Natural History.)

Type locality. — "Nous l'avons découverte dans le sable de la Jamaïque."

Range. — Middle Pliocene to Recent. Recent, Monterey Bay, California, to Panama Bay, in 37 to 160 meters (20 to 88 fathoms). Caribbean region, North Carolina to the West Indies, in 15 to 1256 meters (8 to 687 fathoms).

Occurrence in San Diego Fm. — L.A.M. Loc. 305.

Original description. — Testa rotundato-ovato, compressa, sordidè albida, radiatim 9 costata; costis erectis, elevatis; latere buccali 6 approximatis; anli externè unicostato, in medio 2 approximatis; interstitiis striatis. (d'Orbigny.)

Remarks. — Several valves of this small, rounded, pearly shell were collected by G. P. Kanakoff near the Mexican boundary. The largest specimen is about 4 mm long.

The shape and the presence of eight or nine ribs, chiefly on the anterior two thirds of the valves, easily serve to separate this from other species in the faunal assemblage at San Diego. This is the first record of this species from beds of undoubted Pliocene age in western North America.

Most workers have been unable to detect any constant difference between shells referred to *Verticordia ornata* from east and west American waters. The east American species of this group were discussed by Dall in 1886.

Early records of *V. novemcostata* Adams and Reeve from western North America are now referred to *V. ornata*. The species described by Adams and Reeve is believed to be restricted to Oriental waters.

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(102) See Chavan, A., Schweiz. Palaeo. Abhandl., Vol. 69, No. 3, p. 17, 1952.

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(105) *Barbarca* Dall, Bartsch, and Rehder, Bernice P. Bishop Mus., Bull. 153, p. 23, July 25, 1938. "Type: *Calloarca (Barbarca) hua*, new species," p. 24, pl. 4, figs. 5-8, text fig. 8 (a-c). "on the reef at the entrance to Pearl Harbor, Oahu, on the Honolulu side."

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(194) See Olsson, A. A., Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 130, 1961.

(195) *Crenella ecuadoriana* Pilsbry and Olsson, Proc. Acad. Nat. Sci. Philadelphia, Vol. 93, p. 55, pl. 18, figs. 2 and 3, September 9, 1941. "Canoa formation, Punta Blanca" Ecuador, Pliocene. See also, Olsson, 1961, p. 130, pl. 17, figs. 7, 7a.

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(198) See Burch, J. Q., Min. Conch. Club South. California, No. 37, p. 10, July, 1944.

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(270) *Pecten lunaris* S.S. Berry, Leaflets in Malacol., Vol. 1, No. 23, p. 139, September 30, 1963. "Type-Locality: 30-45 fms., off Morro Colorado, Sonora; Capt. Antonio Luna, Mar. 1963."

(271) *Pecten sericeus* Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, p. 60, pl. 17, figs. 1, 1a, 1844 (January, 1845, on cover of Pt. 3). "Inhab. Bay of Panama. In fifty-three fathoms, on a muddy floor." –Grau, Allan Hancock Pac. Exped., Vol. 23, p. 141, pls. 50, 51, 1959.

(272) *Pecten (Pecten) carrizoensis* Arnold, U.S.G.S., Prof. Paper 47, p. 59, pl. 4, figs. 1, 1a, 1b, 2, 3, and 3a, 1906. From "the head of Garnet Canyon, about 12 miles north of the Mexican boundary, in the Carrizo Creek district, San Diego County." Miocene. [Pliocene.] [On page 152 the type is cited as from Alverson Canyon.]

(273) *Pecten (Pecten) beali* Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 1, p. 10, pl. 2, fig. 3; pl. 5, fig. 8, July 21, 1925. "pebbly sandstone near Comondú-Salada contact, Arroyo near La Palma, Lower California." "Salada, Pliocene."

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(277) *Pecten soror* Gabb, Pilsbry, Proc. Acad. Nat. Sci. Philadelphia, Vol. 73, Pt. 2, p. 410, pl. 44, figs. 1, 2, 1921, issued January 30, 1922.

(278) *Pecten soror codercola* Harris, Bull. Amer. Paleo., Vol. 13, Bull. 49, p. 23, pl. 13, fig. 3; pl. 14, figs. 1, 5; pl. 15, fig. 7, October 7, 1927. "Districts of Democracia and Colina, State of Falcón, locality numbers 69, 123." Venezuela. "Miocene and Pliocene."

(279) See Fitch, J.E., State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 43, fig. 9, 1953.

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(282) *Pecten (Pecten) juanensis* Grant and Stephenson, Jour. Paleo., Vol. 22, No. 6, p. 804, pl. 124, figs. 1-4, November, 1948. "UCLA Locality 435, sandstone fossil reef on east side of valley of San Juan Creek, at elevation of about 1500 feet above sea level, in west middle half of section 32, Township 28 south, Range 16 East (Mount Diablo Base and Meridian), eastern San Luis Obispo County, California. Stratigraphic position: approximately at conformable contact between lower and upper Neroly, lower half of the upper third of the Miocene."

(283) *Pecten coalingaënsis* Arnold in Anderson, Proc. Calif. Acad. Sci., Ser. 3, Geology, Vol. 2, No. 2, p. 197, pl. 18, figs. 94-98, December 4, 1905. "This species is common in the Etchegoin Beds of the Mount Diablo Range, at the Kreyenhagen ranch on Zapata Chino Creek." "probably Pliocene." –Arnold, U.S.G.S., Prof. Paper 47, p. 97, pl. 4, figs. 4, 4a, 5, 1906 (as *Pecten (Pecten) coalingaensis).*

(284) *Pecten (Oppenheimopecten) hancocki* Grau, Allan Hancock Pac. Exped., Vol. 23, p. 154, pl. 57, September 25, 1959. "Chatham Bay, Cocos Island, Costa Rica, in 47 fathoms, coarse white sand."

(285) See *Pecten aduncus* Eichwald, Depéret and Roman, Mém. Soc. Géol. France, Paléo., Tome 10, Fasc. 1, Mém. No. 26, p. 49, pl. 6, figs. 6, 6a, 1902.

(286) *Pecten (Pecten) perulus* Olsson, Mollusks of the tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 158, pl. 20, figs. 3, 3a-c; pl. 21, figs. 3, 3a, March 10, 1961. "Santa Elena, Ecuador. Holotype, ANSP 218918."

(287) See Hoffstetter, R., Bol. Inform. Cienc. Nat. (Quito), Vol. 2, Nos. 13, 14, p. 73, 1948.

(288) See *Patinopecten* sp., Schenck, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 1, p. 28, 1928. Yaquina sandstone,

western Oregon.

(289) Akiyama, M., "Studies on the phylogeny of *Patinopecten* in Japan," Sci. Repts. Tokyo Kyoiku Daigaku, Geol. Min. Geogr., Sec. C, Vol. 8, No. 74, pp. 63-122, pls. 1-8, figs. 1-3, in text, February 5, 1962.

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(291) Masuda, K., "The so-called *Patinopecten* of Japan," Trans. Proc. Palaeo. Soc. Japan, New Ser., No. 52, pp. 145-153, pls. 22, 23, December 10, 1963.

(292) *Blanckenhornia* von Teppner, Foss. Cat. 1: Anim., Edit. a C. Diener, Pars 15, Lamell. Tert., Anisomyaria II, p. 260, 1922. "Typus: *Pecten (Blanckenhornia) oweni* Arnold."

(293) See Jaworski, E., Palaeo. Zeitschr., Bd. 1, Heft 2, p. 296, 1914.

(294) *Fortipecten* Yabe and Hatai, Sci. Rept. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 21, no. 2, p. 149, 1940. "Type: pl. XXXIV (1), Figs. 4-6." [= *Pecten takahashii* Yokoyama, 1930.]

(295) *Pecten (Patinopecten) lohri* Hertlein, Nautilus, Vol. 41, No. 3, p. 93, January, 1928. New name for *Pecten (Patinopecten) oweni* Arnold, U.S.G.S., Prof. Paper 47, p. 63, pl. 8, figs. 1, 1a, 1b, 1906. "Foxin's ranch, Santa Barbara County, Cal." Pliocene. (Not *Pecten oweni* DeGregorio, 1884.)–Hanna and Hertlein, Calif. State Div. Mines, Bull. 118, p. 176, fig. 65-1 (p. 177), 1941. Beds at railroad bridge across Waltham Creek, about 2 miles southwest of Coalinga, Fresno Co., California. Jacalitos formation, lower Pliocene.

(296) The specimen from that region illustrated by the senior author under the name of *Pecten lohri* can be referred to *P. healeyi*. See Calif. State Div. Mines, Bull. 154, p. 189, fig. 2, (on p. 188), 1951.

(297) *Pecten propatulus* Conrad, U.S. Explor. Exped. (Wilkes), Vol. 10, Geol., ap. p. 726, atlas, pl. 18, figs. 13, 13a, 1849. "Astoria, Oregon." Miocene. –Arnold, U.S.G.S., Prof. Paper 47, p. 64, pl. 7, fig. 1; pl. 9, figs. 1, 1a, 2, 2a, 1906 (as *Pecten (Patinopecten) propatulus)*. –Moore, U.S.G.S., Prof. Paper 419, p. 64, pl. 16, figs. 1-4; pl. 17, figs. 2-5, 7, 1963 (as *Patinopecten propatulus)*. (Lectotype.)

(298) *Pecten (Patinopecten) haywardensis* Lutz, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 28, No. 13, p. 386, pl. 17, figs. 9, 10, October 16, 1951. Hayward quadrangle, California; Sobrante Sandstone, middle Miocene.

(299) *Pecten (Patinopecten) haywardensis calaverasensis* Hall, Univ. Calif. Publ. Geol. Sci., Vol. 34, No. 1, p. 51. pl. 2, fig. 2; pl. 3, fig. 4; pl. 4, fig. 3, November 24, 1958. "Middle Miocene, Oursan sandstone."

(300) *Pecten oregonensis* Howe, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 3, p. 98, pl. 11, figs. 1, 2; pl. 12, figs. 1, 2, September 8, 1922. Type locality: West side of Coos Head, mouth of Coos Bay, Oregon. Pliocene. A subspecies, *Patinopecten oregonensis cancellosus* Moore (1963, p. 65, pl. 17, figs. 6, 8, 9; pl. 18, figs. 1, 4) was described from "Dredgings from the Miocene rocks, Coos Bay, Oreg."

(301) *Pecten tryblium* Yokoyama, Jour. Fac. Sci. Imper. Univ. Tokyo, Sec. II, Geol., Vol. 1, Pt. 1, p. 17, pl. 6, figs. 1, 2; pl. 7, figs. 1, 5, August 29, 1925. "Shigarami and Sakae." Japan.

(302) *Pecten yamasakii* Yokoyama, Jour. Fac. Sci. Imper. Univ. Tokyo, Sec. II, Geol., Vol. 1, Pt. 1, p. 17, pl. 5, figs. 1, 2, 4, 5, August 29, 1925. "Shigarami and Togakushi." Japan.– Akiyama, Sci. Repts. Tokyo Kyoiku Daigaku, Geol. Min. Geogr., Sec. C, Vol. 8, No. 74, p. 95, pl. 3, fig. 3; pl. 6, fig. 3, 1962 (as *Patinopecten (Patinopecten) yamasakii yamasakii)*. Early Pliocene of Japan.

(303) Kuroda, T., Fossil Moll. (in F. Homma), Shinano Chûbu Chishitsu-Shi (Geol. Central Shinano), Pt. 4, p. 35, pl. 2, figs. 7, 8, 1931.

(304) *Patinopecten yamasakii ninohensis* Masuda, Saito Ho-On Kai Mus. Res. Bull., No. 23, (Geol., No. 2), p. 13, figs. 1-3, September, 1954. Lowermost Suenomatsuyama Formation in the Iwate Prefecture, Japan; late Miocene.

(305) *Pecten (Patinpopecten) duplex* Cooks, Carnegie Inst. Washington, Publ. 291, p. 140, pl. 11, figs. 10a, 10b, 1919. "Long Island, Antigua, station 6869, Vaughan." "Oligocene." –Olsson and Richards, Notulae Naturae Acad. Nat. Sci. Philadelphia, No. 350, p. 5, pl. 1, figs. 5, 6, 1961 (as *Pecten (Flabellipecten) duplex*). Goajira Peninsula of Colombia. "Probably Upper Oligocene."

(306) *Pecten (Patinopecten) yakatagensis* Clark, Bull. Geol. Soc. Amer., Vol. 43, No. 3, p. 807, pl. 16, fig. 1, September 30, 1932. Yakataga Reef, southeastern Alaska.

(307) *Pecten oregonensis* Howe var., Manning and Ogle, Calif. State Div. Mines, Bull. 148, pl. 6, 1950.

(308) See *Patinopecten (Lituyapecten) falorensis* MacNeil, U.S.G.S., Prof. Paper 354-J, p. 234, pl. 38, figs. 1 and 3, 1961. Falor Formation, Pliocene.

(309) Ogle, B.A., "Geology of Eel River Valley Area Humboldt County, California," Calif. State Div. Mines, Bull. 164, pp. 44-45, 1953.

(310) *Patinopecten (Lituyapecten) poulcreekensis* MacNeil, U.S.G.S., Prof. Paper 354-J, p. 228, pl. 35, figs. 1-6; pl. 36, figs. 1, 2(?), 3, 4, 6, 7; pl. 38, fig. 2, 1961. Type locality, "Uppermost part of the Poul Creek formation at Yakataga Reef, USGS loc. M-271." Early Miocene.

(311) See *Patinopecten (Patinopecten) poculum kurosawaensis* Yokoyama, Akiyama, Sci. Repts. Tokyo Kyoiku Daigaku, Geol., Min. Geogr., Sec. C, Vol. 8, No. 74, p. 101, pl. 4, fig. 3, 1962. See also remarks on pp. 112, 115.

(312) *Pecten (Patinopecten) purisimaensis* Arnold, U.S.G.S., Prof. Paper 47, p. 105, pl. 34, fig. 3; pl. 35, figs. 1, 1a, 1906. "Purisima formation (lower Pliocene), north of the mouth of Pescadero Creek, San Mateo County, Cal." –MacNeil, U.S.G.S., Prof. Paper 354-J, p. 233, pl. 44, figs. 1, 3, 1961 [as *Pecten (Lituyapecten) purisimaensis*].

(313) Arnold, R., and Hannibal, H., "The Marine Tertiary Stratigraphy of the North Pacific Coast of America," Proc. Amer. Philos. Soc. Vol. 52, No. 212, p. 594, 1913.

(314) *Pecten coosensis* Shumard, Trans. St. Louis Acad. Sci., Vol. 1, Pt. 2, p. 122, 1858. "found in great profusion at the mouth of Coos Bay, in slightly coherent sandstone of the Miocene period." –Weaver, Univ. Washington Publ. Geol., Vol. 5, p. 92, pl. 18, figs. 1, 2; pl. 21, figs. 2, 5, 1942 (issued December 31, 1943) (as *Pecten (Patinopecten) coosensis*). –Trumbull, Jour. Paleo., Vol. 32, No. 5, p. 901, pl. 115, figs. 1-4; pl. 116, figs. 1, 2; pl. 117, fig. 4, 1958 (as *Patinopecten coosensis*). [Specimens from type lot illustrated.]

(315) *Patinopecten (Patinopecten) nakatombetsuensis* Akiyama, Sci. Repts. Tokyo Kyoiku Daigaku, Sec. C, Geol. Min. Geogr., Vol. 8, No. 74, p. 100, pl. 4, figs. 2, 5, February 5, 1962. Nakatombetsu Formation, early Pliocene.

(316) See Gillet, S., Mém. Soc. Géol. France, New Sér., Tom. 1, Fasc. 3 and 4, Mém. No. 3, p. 46, 1924.

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(319) Dechaseaux, C., "Pectinidés Jurassiques de l'est du Bassin de Paris," Ann. Paléo., Tom. 25, Fasc. 1-3, pp. 1-148, pls. 1-10, March, 1936.

(320) *Pecten (Chlamys) lawsoni* Arnold, U. S. G. S., Prof. Paper 47, p. 117, pl. 45, figs. 3, 4, 1906.

(321) See Adegoke, O. S., Univ. Calif. Publ. Geol. Sci., Vol. 80, p. 97, 1969.

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(326) See Bavay, E., Jour. de Conchyl., Vol. 79, No. 4, p. 309, 1936.

(327) See *Chlamys odontata* Cox, Proc. Malacol. Soc. London, Vol. 18, Pt. 5, p. 205, July 15, 1929.

(328) According to A. M. Keen (Veliger, Vol. 2, No. 4, p. 101, April, 1960), *hericius* "is a noun, not an adjective, derived from the latin word *ericius*, hedgehog."

(329) *Pecten (Chlamys) miyatokoensis* Nomura and Hatai, Saito Ho-On Kai Mus., Res. Bull., No. 13, p. 127, pl. 19, figs. 2-4; pl. 20, fig. 1, August, 1937. "Otutumi" and "Sabusawa," Japan, Miocene.—Masuda, Trans. Proc. Palaeo. Soc. Japan, New Ser., No. 24, p. 247-250, pl. 35, figs. 1-9b, 1956 (as *Chlamys miyatokoensis*).

(330) See Masuda, K., Trans. Proc. Palaeo. Soc. Japan, New Ser., No. 22, p. 176, pl. 29, figs. 1-7, 1956. (See remarks p. 179).

(331) *Pecten kaneharai* Yokoyama, Jour. Fac. Sci. Imper. Univ. Tokyo, Sec. 2, Vol. 1, Pt. 4, p. 135, pl. 8, fig. 1; pl. 19, figs. 1,2,5-7, January 9, 1926. Shiobara in Shimotsuké, Japan, Pliocene. See also, Makiyama, J., Palaeo. Soc. Japan, Spec. Papers No. 4, pl. 36, fig. 1; pl. 37, figs. 1, 2, 5, 6, 7, 1958.

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(334) Gregg, W. P., Nautilus, Vol. 51, No. 4, p. 118, April, 1938.

(335) See Henderson, J., Univ. Colorado Studies, Vol. 16, No. 1, p. 2, June, 1927.

(336) The altitude of the type specimen was given as 51 mm. in the explanation of plate 12, figure 6, in the original publication. This apparently was an error because Arnold in 1906 gave the altitude as 45 mm. and measurements of his illustration substantiate this figure.

(337) See *Pecten (Pecten)* cf. *islandicus* var. *jordani* Arnold, Kundert, Calif. State Div. Mines, Spec. Rept. 18, p. 15, 1952. Whittier-LaHabra area, California, Pico Formation, Pliocene.

(338) See *Chlamys islandicus jordani* Arnold, Woodring, U. S. G. S., Prof. Paper 207, p. 80, pl. 32, fig. 16, 1946. "Timms Point silt," San Pedro, California, Pleistocene.

(339) See *Pecten (Chlamys) jordani* Arnold, I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 19, pl. 2, figs. 1, 2, 1924.—I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 55, pl. 28, figs. 5, 6, 1924.

(340) *Pecten (Chlamys) hindsii kincaidi* I. S. Oldroyd, Publ. Puget Sound Biol. Sta., Vol. 4, p. 17, pl. 9, figs. 3, 4, 1924. "Off San Juan Island, Wash., in 25 fathoms.—Puget Sound."—I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, p. 53, pl. 12, figs. 1, 2, 1924.

(341) See *Chlamys rubida jordani* Arnold, Grau, Allan Hancock Pac. Exped., Vol. 23, p. 79, pl. 25, 1959.

(342) See *Pecten (Chlamys) hindsii* var. *jordani* Arnold, Crickmay, Canadian Field Nat., Vol. 39, No. 6, p. 140, 1925. Road cut on Pacific highway on South side of Fraser River opposite New Westminster, British Columbia, Pleistocene; Vol. 43, No. 9, p. 206, 1929. Surrey, British Columbia, Pleistocene.

(343) *Chlamys durhami* Adegoke, Univ. Calif. Publ. Geol. Sci., Vol. 80, p. 97, pl. 2, fig. 5, September 25, 1969.

(344) See Masuda, K., Trans. Proc. Palaeo. Soc. Japan, New Ser., No. 13, pp. 112-115, pl. 12, figs. 1-7 (*Chlamys nisataiensis*), 8-17 (*Chlamys akitana*), June 15, 1954. Early and Middle Miocene.

(345) *Pecten (Chlamys) hertleini* Loel and Corey, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 22, No. 3, p. 195, pl. 20, figs. 4, 6, 7, 8, December 31, 1932. "Univ. Calif. Coll. Invert. Pal., loc. 5-15 R. N. N. Santa Ynez River Canyon, Santa Barbara County." Vaqueros Formation, early Miocene.

(346) *Chlamys tamurae* Masuda and Sawada, Jap. Jour. Geol. Geogr., Vol. 32, No. 1, p. 27, pl. 4, figs. 12a-b, 13, 14, 15, March 20, 1961. "Small hill-side exposure at Maruyama, Kita-Hiyama-machi, Setana-gun, Shiribeshi Province, Hokkaido (Lat. 40°23′56″N., Long. 139°54′55″E.). Setana formation. Pliocene."

(347) See Grant, U. S., IV, Amer. Assoc. Petrol. Geol., Program 22nd Mtg., pp. 69-71, March 18, 1937. Also see remarks by J. W. Valentine concerning the conditions of deposition of the strata exposed at and near Lomita Quarry (Univ. Calif. Publ. Geol. Sci., Vol. 34, No. 7, pp. 411-413, 1961).

(348) See Yates, A., Santa Barbara Soc. Nat. Hist. Bull., No. 2, p. 41, August, 1890. Santa Rosa Island, California "(Southern limit)."

(349) *Pecten (Chlamys) islandicus picoensis* Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, p. 83, pl. 5, figs. 2 and 4, April 6, 1929. "Type from top of Pico, U. C. Loc. 7100, NW corner Sec. 3, T 3N, R 21W, Ventura County, California."

(350) *Pecten (Chlamys) venturaensis* Waterfall, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 3, p. 84, pl. 6, fig. 4, April 6, 1929. "Type from top of Pico, U. C. Loc. 7097, east center of Sec. 21, T 3N, R 21W, Ventura County, California." (Cited in table opp. p. 78 as "*Pecten (Chlamys) washburnei venturaensis* n. subsp.")

(351) The brackets are by Carpenter.

(352) For references to this species see footnote 340.

(353) MacNeil, F. S., "Cenozoic Megafossils of Northern Alaska," U.S.G.S., Prof. Paper 294-C, pp. 114-115, pl. 14, fig. 1, 1957.

(354) See I. S. Oldroyd, Amer. Malacol. Union, Seventh Ann. Mtg. at University of Michigan, Ann Arbor, Michigan [p. 2 (not paginated), January 1, 1938].

(355) See *Chlamys islandica hindsi* Carpenter, Kira, Shells of the western Pacific in color (Hoikusha Publ. Co.: Osaka, Japan), p. 140, pl. 50, fig. 9, 1962. In cold waters from Hokkaido to Alaska.

(356) See Oyama, K., and Takemura, Y., The molluscan shells (Science and Photography Club: Tokyo, Japan), II, *Pecten*, pl. 5, figs. 1-3, 1958. "off Kuji."

(357) See Kuroda, T., and Habe, T., Check List and Bibliography of the Recent Marine Mollusca of Japan (Publ. by Leo Stach: Tokyo, Japan), p. 16, 1952.

(358) See Dautzenberg, P., and Bavay, A., Siboga Exped., Monogr. 53b, Pectinidae, p. 12, 1912.

(359) *Chlamys imanishii* Masuda and Sawada, Jap. Jour. Geol. Geogr., Vol. 32, No. 1, p. 25, pl. 4, figs. 10a-c, 11, March 20, 1961. "Sea cliff at Hamada, Yokohama-mura, Kami-Kita-gun, Aomori Prefecture (Lat. 41°08′15″N., Long. 141°16′34″E.). Hamada formation. Early Pliocene."

(360) *Chlamys ingeniosa tanakai* Akiyama, Trans. Proc. Paleo. Soc. Japan, New Ser., No. 31, p. 243, pl. 36, figs. 1, 2a, 2b, 3a, 3b, August 15, 1958. "Kawashita, Togakushi-mura, Kamiminochi-gun. Lat. 36°40′14.5″N, Long. 138°5′46″E." Nagano Prefecture. "Ogikubo sandstone and mudstone member."

(361) See Willett, G., Bull South. Calif. Acad. Sci., Vol. 45, Pt. 1, p. 29, 1946.

(362) See Peck, J. H., Jr., Univ. Calif. Publ. Geol. Sci., Vol. 36,

No. 4, p. 236, (table, not paginated), 1960.

(**363**) See Nomland, J. O., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 10, No. 14, p. 219, and table opp. p. 230, 1917.

(**364**) See Stewart, R. B., in Woodring, W. P., Stewart, R. B., and Richards, R. W., "Geology of the Kettleman Hills Oil Field California," U.S.G.S. Prof. Paper 195, p. 91, 1940 (1941).

(**365**) Waller, T. R., "The Evolution of the *Argopecten gibbus* stock (Mollusca: Bivalvia), with Emphasis on the Tertiary and Quaternary species of eastern North America," Jour. Paleo., Vol. 43, Suppl. to No. 5 (Paleo. Soc., Mem. 3), pp. I-V, 1-125, pls. 1-8, text figs. 1-13, data tables 1-43, September, 1969.

(**366**) See Dollfus, G. F., Mém. Soc. Géol. France, Paléo., Vol. 18, Fasc. 3-4, (Mém. No. 44), p. 62, pl. 4, figs. 34, 35, 1911.

(**367**) *Pecten (Plagioctenium) neahensis* Arnold, U.S.G.S., Prof. Paper 47, p. 87, pl. 15, figs. 2, 2a, 2b, 1906. "Miocene, Strait of Fuca, east of Neah Bay, Clallam County, Wash." See also Weaver, [1942 (1943), p. 90] concerning the occurrence of this species.

(**368**) *Pecten (Plagioctenium) abietis* E. K. Jordan and L. G. Hertlein, Proc. Calif. Acad. Sci., Fourth Ser., Vol. 15, No. 4, p. 214, pl. 23, figs. 1, 3, 7, April 26, 1926. "Arroyo Hondo, Maria Madre Island, Mexico; upper Pliocene."–Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 62, pl. 10, figs. 4, 7; pl. 11, fig. 4, 1950 (as *Aequipecten abietis*). –Emerson and Hertlein, Trans. San Diego Soc. Nat. Hist., Vol. 13, No. 17, p. 354, figs. 4a-c, 1964 (as *Chlamys (Argopecten) abietis*). (With synon.)

(**369**) For reference concerning *C. (A.) circularis aequisulcata*, see footnote 370.

(**370**) *Pecten aequisulcatus*, ?n.s., Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 645, August, 1864. Reprint in Smithsonian Miscell. Coll., No. 252, p. 131, 1872. Indicated as from neighborhood of Santa Barbara and the region between San Diego and San Pedro, California. See also, Carpenter, 1864, pp. 536, 540, 592, 599; reprint, 1872, pp. 22, 26, 78, 85. San Diego and San Pedro, California. –Arnold, U.S.G.S., Prof. Paper 47, p. 132, pl. 50, figs. 1, 1a, 1b; text fig. 1, p. 45, fig. 2, p. 46, 1906 (as *Pecten (Plagioctenium) circularis* Sowerby var. *aequisulcatus*). Pleistocene and Recent.–K. V. W. Palmer, Geol. Soc. Amer., Mem. 76, p. 71, pl. 3, figs. 1-3, 1958 (as *Pecten (Plagioctenium) circularis aequisulcatus*). "Recent. San Diego, California (type)." Also other localities.

(**371**) *Ostrea gibba* Linnaeus, Syst. Nat., ed. 10, p. 698, 1758. Ref. to "Brown, jam. t. 40, f. 10." "Habitat in M. Americano."–Reeve, Conch. Icon., Vol. 8, *Pecten*, sp. 37, pl. 9, figs. 37b, 37c, 1852 (as *Pecten gibbus*). For a discussion of this species see Tucker-Rowland (1938, pp. 44-46, pl. 4, fig. 21); Dodge, Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 182-183, 1952; Waller, 1969, pp. 36-38, pl. 8, figs. 1-4, 1969.

(**372**) Davenport, C. B., "Comparison of some pectens from the east and the west coasts of the United States." Mark Anniversary Volume, Art. 6, pp. 121-136, pl. 9, 1903.

(**373**) See Weisbord, N. E., Bull. Amer. Paleo., Vol. 45, No. 204, pp. 150-152, 1964.

(**374**) *Pecten (Plagioctenium) calli* Hertlein, Proc. Calif. Acad. Sci. Ser. 4, Vol. 14, No. 1, p. 16, pl. 4, figs. 5, 6, 7, July 21, 1925. "first arroyo east of Santiago, Lower California." "Miocene?" [Pliocene].–E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 436, pl. 27, fig. 5, 1926. "Pliocene beds exposed about a prominent monadnock, from one to two miles to southeast of Turtle Bay. Upper Pliocene." Also other localities.

(**375**) Durham, J. W., Geol. Soc. Amer., Mem. 43, Pt. 2, p. 63, 1950.

(**376**) *Aequipecten circularis* subsp. *bramkampi* Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 63, pl. 9, figs. 2, 4, 8, August 10, 1950. From Loc. A1268 (U.C.) Imperial Formation, northwest side of Carrizo Mountain, Imperial Co., California. Pliocene.

(**377**) *Pecten (Plagioctenium) eldridgei* Arnold, U.S.G.S., Prof. Paper 47, p. 87, pl. 25, figs. 3, 3a, 3b, 4, 4a, 5, 5a, 6, 1906. "San Pablo formation (upper Miocene), McKittrick district, Kern County, Cal."[Pliocene.]–Woodring and Stewart, U.S.G.S., Prof. Paper 195, p. 91, pl. 24, figs. 10-13, 1940 (1941) (as *Aequipecten circularis eldridgei*). Kettleman Hills, California; San Joaquin Formation, late Pliocene.

(**378**) *Pecten deserti* Conrad, House Document 129, Projected Vol. 3, 33rd Congress, 1st session, July, 1855, p. 15. "Locality.–Carrizo creek, Colorado desert. Miocene." [On page 5, Conrad mentioned "*Pecten vespertinus*" "occurring in the bank of Carrizo creek." No description ever appeared and presumably this form was named *Pecten deserti*.]–Conrad, Pac. Railroad Expl., Vol. 5, p. 325, pl. 5, fig. 41, 1857.

(**379**) *Pecten (Plagioctenium) deserti* Conrad, Arnold, U.S.G.S., Prof. Paper 47, p. 85, pl. 26, figs. 1, 2, 2a, 3, 4, 4a, 1906.–See also Nomland, Univ. Calif. Publ., Bull. Dept. Geol., Vol. 10, No. 14, p. 232 (in text), pl. 6, figs. 1, 1a, 1b, 1917; Hanna, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 18, p. 470, pl. 25, figs. 1, 2, 3, 1926; Mansfield, U.S.G.S., Prof. Paper 170-D, pl. 17, figs. 3, 6, 1932.

(**380**) *Pecten circularis cornellanus* F. and H. Hodson, Bull. Amer. Paleo., Vol. 13, No. 49, p. 26, pl. 14, fig. 2; pl. 15, figs. 3, 10; pl. 16, fig. 3, October 7, 1927, Venezuela, "Age: Miocene."

(**381**) *Pecten circularis venezuelanus* F. and H. Hodson, Bull. Amer. Paleo., Vol. 13, No. 49, p. 25, pl. 14, fig. 6; pl. 15, figs. 2, 4, 5; pl. 17, fig. 1, October 7, 1927. Venezuela. "Age: Miocene and Pliocene."

(**382**) *Pecten circularis caucanus* F. and H. Hodson, Bull. Amer. Paleo., Vol. 13, No. 49, p. 27, pl. 15, figs. 1, 8, October 7, 1927. "District of Democracia, State of Falcón," Venezuela. "Age: Pliocene."

(**383**) *Pecten (Plagioctenium) demiurgus* Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 718, pl. 26, fig. 3, April, 1898. "From the Caroni Series of Trinidad at Savanetta; Guppy."

(**384**) Vokes, H. E., in Wilson, I. F., Bull. Amer. Assoc. Petrol. Geol., Vol. 32, No. 9, pp. 1782, 1783, 1948. Also Vokes, in Wilson, I. F., and Rocha, V. F., U.S.G.S., Prof. Paper 273, pp. 36, 39, 1955.

(**385**) *Pecten (Plagioctenium) cristobalensis* Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 14, No. 1, p. 19, pl. 3, figs. 1, 2, 5, July 21, 1925. "Slopes of Salada three miles southeast of Turtle Bay, uppermost beds, San Cristobal Bay Quadrangle, Lower California." "Salada, Pliocene."

(**386**) *Pecten purpuratus* Lamarck, Hist. Nat. Anim. s. Vert., Vol. 6, p. 166, 1819. "Habite les mers orientales et australes."[Western South America.]–Delessert, Recueil Coquilles, décrites par Lamarck et non encore figurées, pl. 16, figs. 5a, 5b, 5c, 1841.–Reeve, Conch. Icon., Vol. 8, *Pecten*, sp. 25, pl. 5, fig. 25, 1852. "Bay of Callao, Peru."–Küster, Martini u. Chemnitz Conchyl. -Cab., Bd. 7, Abt. 2, p. 78, taf. 20, figs. 1-3, 1888. "Küsten von Peru und Chili."

(**387**) See Woodring, W. P., in Hoots, H., U.S.G.S., Prof. Paper 165, p. 119, 1931.

(**388**) See Oakshott, G. B., California State Div. Mines, Bull. 172, p. 80, 1958 (identification by W. E. Ford).

(**389**) See Winterer, E. L., and Durham, D. L., U.S.G.S., Prof. Paper 334-H, p. 302, 1962 (as "cf. *Aequipecten purpuratus*." Identification by W. P. Woodring, J. G. Vedder, and Ellen J. Trumbull).

(**390**) See Vokes, H. E., in Wilson, I. F., Bull. Amer. Assoc. Petrol. Geol., Vol. 32, No. 9, pp. 1783, 1784, 1948.

(**391**) *Aequipecten antonitaensis* Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 62, pl. 9, figs. 1, 5, August 10, 1950.

(**392**) *Chlamys (Argopecten) coopericellus* Ferreira, Arquivos do Mus. Nacional, (Rio de Janeiro), Vol. 50, p. 150, pl. 2, fig. 4, December 31, 1960. Pirabas Formation, early Miocene.

(**393**) *Pecten cooperi* [Arnold], Kryshtofovich, The Pacific, Russian Scientific Investigations, Acad. Sci. USSR., (Leningrad), 1926, opp. p. 80.

(**394**) *Pecten impostor* Hanna, Proc. Calif. Acad. Sci., Ser. 4, Vol. 13, No. 10, p. 177, March 18, 1924. New name for *Pecten proteus*

Nomland, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 10, No. 14, p. 232, pl. 6, figs. 2, 2a, 2b, 2c, April 9, 1917. Type from Loc. 2991 (UC), "Near center of SE ¼ Sec. 17, T. 22 S, R. 16 E. on top of ridge south of road. *Pecten coalingensis zone*" (p. 230). Not *Pecten proteus* Sowerby, 1847.

(395) For references to this species see footnotes 378 and 379.

(396) See *Aequipecten circularis impostor* Hanna, Woodring and Stewart, U.S.G.S., Prof. Paper 195, p. 91, pl. 13, figs. 3, 4, 1940 (June 7, 1941). *Pecten* zone, Kettleman Hills, California. San Joaquin Formation, late Pliocene.

(397) *Pecten eboreus* var. *senescens* Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 751, pl. 29, fig. 5, April, 1898. "Pliocene of the Waccamaw beds, South Carolina; Johnson."–Tucker-Rowland, Mém. Mus. Roy. Hist. Nat. Belgique, Deuxième Sér., Fasc. 13, p. 50, pl. 4, fig. 15, 1938 (as *Chlamys (Plagioctenium) eboreus senescens* Dall).

(398) *Chlamys eboreus walkerensis* Tucker, Amer. Midland Nat., Vol. 15, No. 5, p. 616, pl. 27, fig. 3, 1934. "Waccamaw Pliocene. Walkers, N. C. (type)."

(399) *Chlamys (Argopecten) imitata* Weisbord, Bull. Amer. Paleo., Vol. 45, No. 204, p. 152, pl. 26, figs. 5-10, February 18, 1964. Playa Grande Formation (Catia Member).

(400) Vokes, H. E., in Wilson, I. F., Bull. Amer. Assoc. Petrol. Geol., Vol. 32, No. 9, pp. 1782, 1783, 1948.–Vokes, H. E., in Wilson, I. F., and Rocha, V. L., U.S.G.S., Prof. Paper 273, pp. 36, 39, 1955.

(401) *Pecten (Leptopecten) praevalidus* E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 435, pl. 29, figs. 2 and 3, July 22, 1926. "Southeast of Turtle Bay, Lower California; upper Pliocene."

(402) *Chlamys (Antipecten) sacyi* Cossmann and Peyrot, Act. Soc. Linn. de Bordeaux, Vol. 68, (Conch. Néogéne de L'Aquitaine, Vol. 2, Livr. 2), p. 338, pl. 15, figs. 12, 13, 15-19, August, 1914. "Cestas (pré Cazeaux)." See also Roger, 1939, p. 65, pl. 2, fig. 8; pl. 3, figs. 6, 6a.

(403) Cossmann, M., in Cossmann and Peyrot, 1914, p. 313. "(G.-T.: *Chl. Sacyi* nov. sp. Mioc.)"

(404) *Pecten (Chlamys) latiauritus* Conrad var. *delosi* Arnold, U.S.G.S., Prof. Paper 47, p. 130, pl. 46, figs. 9, 9a, 10, 10a, 1906. "San Pedro formation (lower portion), Pleistocene, Deadman Island, near San Pedro, Los Angeles County, Cal."

(405) See Webb, R. W., Trans. San Diego Soc. Nat. Hist., Vol. 8, No. 24, p. 345, 1937.

(406) *Chlamys (Leptopecten) desultoria* Weisbord, Bull. Amer. Paleo., Vol. 45, No. 204, p. 145, pl. 15, figs. 3-6, February 18, 1964.

(407) Woodring, W. P., "Lower Pliocene Mollusks and Echinoids from the Los Angeles Basin, California." U.S.G.S., Prof. Paper 190, p. 6, 1938.

(408) See Arnold, R., in Branner, J. C., Newsome, J. F., and Arnold, R., U.S.G.S., Folio 163, p. 6, 1909.

(409) Jordan, E. K., and Hertlein, L. G., "Contributions to the Geology and Paleontology of the Tertiary of Cedros Island and Adjacent Parts of Lower California," Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 418, 1926.

(410) *Aequipecten (Leptopecten) camerella* Berry, Leaflets in Malacol., Vol. 1, No. 25, p. 155, September 26, 1968. "Type-Locality: 35-40 fms., region of La Ribera, Baja California Sur" . . . .

(411) See *Chlamys (Leptopecten) cf. latiaurata* (Conrad, 1837), Ferreira, Arquivos do Mus. Nacional (Rio de Janeiro), Vol. 50, p. 152, pl. 4, fig. 3, December 31, 1960. "Mioceno inferior: Formação Pirabas."

(412) *Aequipecten (Leptopecten) cracens* Olsson, Neogene Mollusks from Northwestern Ecuador (Paleo. Res. Inst.: Ithaca, New York), p. 36, pl. 3, figs. 7, 7a, October 28, 1964. Angostura Formation, "Telembi, Río Cayapas."

(413) Coe, W. R., "Season of Attachment and Rate of Growth of Sedentary Marine Organisms at the Pier of the Scripps Institution of Oceanography, La Jolla, California," Bull. Scripps Inst. Oceanogr. Univ. Calif., Tech. Ser., Vol. 3, No. 3, pp. 37-86, pls. 1-6, figs. 1-3 in text, March 4, 1932. [See especially pp. 60-61, pls. 4-5.] See also Coe, W. R., "Development of the Reproductive System and variations in Sexuality in *Pecten* and other Pelecypod Mollusks," Trans. Connecticut Acad. Arts Sci., Vol. 36, pp. 673-700, figs. 1-8 in text, July 1945. [See especially pp. 680-681, figs. 1, 2.]

(414) Williams, Woodbridge, pers. comm. September 2, 1947.

(415) See Futterer, K., Palaeo. Abhandl., Neue Folge, Bd. 2, Heft 1, p. 79, 1892.

(416) *Pecten (Chlamys) hamlini* Arnold, U.S.G.S., Prof. Paper 47, p. 67, pl. 11, fig. 2, 1906. "Miocene (lower?), head of Slacks Canyon, Monterey County, Cal."

(417) *Pecten praevasseli* de Böckh and Richardson, in Douglas, Contributions to Persian Palaeontology, III, p. 6, pl. 10, figs. 3, 4, September, 1928. (P. 18) "Middle Miocene limestone, near Champeh, Persia." See also Eames and Cox, Proc. Malacol. Soc. London, Vol. 32, pts. 1 & 2, p. 35, pl. 14, figs. 1, 2, 1956.

(418) *Pecten natoriensis* Matsumoto, Sci. Rept. Tohoku Imper. Univ. Sendai, Japan, Ser. 2, (Geol.), Vol. 13, No. 3, p. 104, pl. 40, figs. 10, 11, 1930. Natori district, Japan, "Upper Miocene."

(419) Hatai, K. M., and Nisiyama, S., Saito Ho-On Kai Mus., Res. Bull. No. 6, pp. 100-102, 1935.

(420) Hatai, K. M., and Nisiyama, S., Trans. Proc. Palaeo, Soc. Japan, No. 14, p. 43 (9), 1939 (Reprinted from Jour. Geol. Soc. Japan, Vol. 46, No. 544).

(421) *Nanaochlamys* Hatai and Masuda, Trans. Proc. Palaeont. Soc. Japan, New Ser., No. 11, p. 76, September 30, 1953. "Genotype:-*Pecten notoensis* Yokoyama, 1929." Described and illustrated p. 77, pl. 7, figs. 1-7 and text figs. 2, 3. "Type locality:–Calcareous sandstone of the Miocene Nanao formation at Iwaya, Nanao City, Ishikawa Prefecture." "Geological range:–Early Miocene." See also Masuda, K., "On the morphogenesis of *Nanaochlamys*," Sci Repts. Tohoku Univ., Sendai, Japan, 2nd Ser. (Geol.), Spec. Vol. No. 4, pp. 371-383, pl. 39, figs. 1-10 in text, March, 1959.

(422) *Decatopecten* Rüppel in Sowerby, Conch. Manual, p. 37, 1839. Sole species, *"Pecten Plica*, Linn. Fig. 172." In later editions as *Decadopecten*. According to Sherborn, the original spelling is "err. typ. pro *Decado-*." See also Treatise on Invert. Paleo., Part N, Vol. 1, p. N365, 1969.

(423) *Anguipecten* Dall, Bartsch, and Rehder, Bernice P. Bishop Mus., Bull. 153, p. 92, July 25, 1938. "Type: *Anguipecten gregoryi*, new species," p. 93, pl. 23, figs. 5, 6, 8. Recent, Hawaii.

(424) *Manupecten* Monterosato, Jour. de Conchyl., Vol. 37, (Ser. 3, Vol. 29), No. 1, p. 21, issued May 2, 1889.–Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 24, p. 36, December, 1897. "(tipo *M. pesfelis* (L.))."

(425) *Felipes* Loc., Carus, Faunae Mediterr., Vol. 2, Pt. 1, p. 71, 1889-1893 (issued December, 1889). [Concerning dates of publication of *Felipes*, see Tucker-Rowland, H. I., Bull. Mus. Roy. d'Hist. Nat. Belgique, Tom. 14, No. 49, p. 8, August, 1938.]–Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 696, 1898. *Felipes* "with *P. pesfelis* as the type." [*Pelipes* error pro *Felipes* Carus, Haas, Klassen and Ordnung des Tierreichs, 2.2, p. 292, 1938.]

(426) *Semipallium* Jousseaume in Lamy, Bull. Mus. Nat. Hist. Nat. Paris, Ser. 1, Vol. 34, No. 2, p. 169, 1928. Type (by monotypy): *Pecten tigris* Lamarck. Illustrated by Chenu, Illustr. Conchyl., Pts. 29, 30, p. 7, pl. 27, figs. 3, 3a, 4, 4a, 1844.–Chenu, Man. de Conchyl., Vol. 2, p. 183, fig. 924, 1862.

(427) *Mesopeplum* Iredale, Rec. Australian Mus., Vol. 17, No. 4, pp. 162, 188, September 4, 1929. "Type *Mesopeplum caroli* Iredale," p. 162, pl. 38, figs. 7, 8, 9. "Trawled in 40-80 fathoms off the New South Wales coast."

(428) *Notochlamys* Cotton, Rec. South Australian Mus., Vol. 4, No. 2, p. 233, July 18, 1930. Type (by original designation): *Chlamys anguineus* Finlay = *P. undulatus* Sowerby. [This supraspecific unit is very similar to *Mesopeplum*. It was de-

scribed as differing in possessing fine shagreen sculpture and in lacking concentric threads.]

(429) *Anatipopecten* Hertlein, Nautilus, Vol. 50, No. 1, p. 26, July 1936. "with *Pecten anatipes* Morton as type." Illustrated by Rowland, Amer. Midland Nat., Vol. 17, No. 6, p. 1004, pl. 7, fig. 2; pl. 10, fig. 13, November, 1936. Vicksburg, Oligocene.

(430) *Stralopecten* Rowland, Jour. Conch., Vol. 21, No. 5, p. 81, September 22, 1938. Type (by original designation): *Stralopecten ernestsmithi* Tucker, illustrated in Mém. Mus. Roy. Hist. Nat. Belgique, Deuxième Sér., Fasc. 13, p. 27, pl. 2, fig. 7, 1938. Originally described in Proc. Indiana Acad. Sci., Vol. 40, pp. 244, 245, pl. 1, figs. 3, 4, 1931. North Carolina, Pliocene.

(431) *Pecten etchegoini* F. M. Anderson, Proc. Calif. Acad. Sci., Ser. 3, Vol. 2, No. 2, p. 198, pl. 18, figs. 92, 93, December 4, 1905. "Etchegoin Beds of the Kreyenhagen ranch on Zapata Chino Creek."—Stewart, in Woodring, Stewart, and Richards, U.S.G.S., Prof. Paper 195, p. 91, pl. 13, fig. 5; pl. 32, fig. 1, 1940 (1941) (as *Chlamys etchegoini*).

(432) *Pecten (Chlamys) hamlini* Arnold, U.S.G.S., Prof. Paper 47, p. 67, pl. 11, fig. 2, 1906. "Miocene (lower?), head of Slacks Canyon, Monterey County, Cal."

(433) *Pecten (Chlamys) nutteri* Arnold, U.S.G.S., Prof. Paper 47, p. 67, pl. 11, figs, 3, 4, 4a, 1906. "Purisima formation (lower Pliocene), south of mouth of San Gregorio Creek, San Mateo County, Cal." (Type.)

(434) *Pecten (Chlamys) wattsi* Arnold, U.S.G.S., Prof. Paper 47, p. 120, pl. 11, figs. 1, 1a, 1906. "The type is from Kreyenhagen's Ranch, Fresno County." [A lectotype, No. 5945, is in the series of type specimens in the department of Geology, California Academy of Sciences. See Hanna, G D., and Hertlein, L. G., Calif. State Div. Mines, Bull. 118, Pt. 2, p. 176, pre-print August, 1941, made available September 11, 1941.]

(435) *Pecten (Chlamys) wattsi* var. *morani* Arnold, U.S.G.S., Prof. Paper 47, p. 121, pl. 10, figs. 3, 4, 5, 6, 1906. "Pliocene (lower). T. H. Moran's place, SW. ¼ sec. 14, T. 20S., R. 12 E., Mount Diablo Meridian, Priest Valley, Monterey County (Hamlin and Arnold)."

Reagan (Trans. Kansas Acad. Sci., Vol. 22, pp. 172, 198, 1909) reported the occurrence of "*Pecten (Chlamys) wattsi* var. *morani* Arnold?" from beds exposed at East Clallam, western Washington. We have not seen specimens from that area.

(436) *Pecten (Chlamys) kindlei* Dall, U.S.G.S., Prof. Paper 125-C, p. 30, pl. 6, figs. 2, 7, 1920. "Pliocene of Center Creek Mines, 2 miles north of Nome, from the second beach." Alaska.—MacNeil, Jour. Paleo., Vol. 17, No. 1, p. 87, pl. 12, figs. 7, 8, 1943 (as *Pecten (Manupecten) kindlei*). Intermediate Beach, near Nome, Alaska, Pliocene. ?Second Beach, fragment.

(437) *Chlamys (Swiftopecten) donmilleri* MacNeil, U.S.G.S., Prof. Paper 553, p. 12, pl. 3, figs. 1, 4, 6, 1967. "Type locality: 1,500 ft above base of Yakataga Formation (horizon probably middle Miocene), south side of White River near foot of glacier, Yakataga district, Alaska, USGS 6694."

(438) See Arnold, R., U.S.G.S., Bull. 396, p. 77, 1909 (issued January 15, 1910.)

(439) See Nomland, J. O., Univ. Calif. Publ. Geol., Vol. 10, No. 14, p. 239, pl. 7, figs. 1-5; pl. 8, figs. 2, 2a, 2b, April 19, 1917.

(440) Clark, B. L., in Santillan, M., and Barrera, T., Ann. Inst. Geol., Vol. 5, p. 25, 1930. "en las terrazas al E. de San Quintîn y entre Colnett y San Isidro." Pliocene.

(441) See Hertlein, L. G., and Allison, E. C., Bull. South. Calif. Acad. Sci., Vol. 58, Pt. 1, p. 21, 1959.

(442) *Pecten (Pallium) swiftii* Bernardi var *etchegoini* Anderson, Slodkewitsch, Paleo. USSR. Tertiary Pelecypoda from the Far East (Acad. Sci., USSR.) Vol. 10, Pt. 3, Fasc. 18, p. 179, 1938; also Fasc. 19, p. 109, pl. 28, figs. 1, 2, 2a, 3, 3a, 4, 5a; pl. 29, fig. 5, 1938.

(443) See Cummings, J. C., Touring, R. M., and Brabb, E. E., Calif. Div. Mines and Geol., Bull. 181, p. 200, photo 15, No. 2, 1962. Tahana member of the Purisima Formation, Pliocene.

(444) Smith, J. P., Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, p. 161, 1919.

(445) *Pecten (Lyropecten) hopkinsi* Olsson, Bull. Amer. Paleo., Vol. 19, Bull. No. 68, p. 83, pl. 5, figs. 1, 4, June 30, 1932. "Tumbez formation, Que. Tucillal at Zorritos." Peru, Miocene.

(446) Hass, O., Jour. Paleo., Vol. 16, No. 3, p. 309, May, 1942.

(447) See Dollfus, G. F., Jour. de Conchyl., Vol. 56, No. 1, pp. 64-66, August 25, 1908.

(448) Clark, B. L., and Durham, J. W., in Schenck, H. G., and Childs, T. S., Jr., Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 3, No. 2, pp. 61 (37)-62 (38), 1942.

(449) North, K. F., (pers. comm.).

(450) *Macrochlamis* Sacco, Bol. Mus. Zool. e Comp. Anat. (Torino), Vol. 12, No. 298, p. 101, June, 1897. "*Macrochlamis latissima* (Br.) (tipo del nuovo sottog.)." Sacco changed the spelling to *Macrochlamys* in Moll. Terr. Terz. Piemonte e Liguria, Pt. 24, p. 32, December, 1897. Not *Macrochlamys* Benson, 1832. According to the present rules of the Internatl. Comm. Zool. Nomencl., the earlier spelling by Sacco can be considered valid. Thus neither of the appropriate names *Gigantopecten* nor *Grandipecten* is available for this taxon.

(451) *Pecten antiguensis churuguarensis* F. and H. Hodson (Bull. Amer. Paleo., Vol. 13, No. 49, p. 35, pl. 20, figs. 1, 3, 4; pl. 22, fig. 2, October 7, 1927) described from beds said to be of "Oligocene" age in Venezuela, is a typical *Amussiopecten*. It bears a resemblance to some varieties of *Pecten burdigalensis* Lamarck, the type of *Amussiopecten*. See for example, *Amussiopecten burdigalensis* var. *spinosella* Sacco Moll. Terr. Terz. Liguria e Piemonte, Pt. 24, p. 53, pl. 15, fig. 9, December, 1897. "Vignale," Italy, Helvetian, Miocene.

(452) *Nodipecten* Dall, Trans. Wagner Free Inst. Sci., Vol. 3, Pt. 4, p. 695, April, 1898. "Type *P. nodosus* L."

(453) Roger, J., Mém. Soc. Géol. France, New Ser., Vol. 17, Fasc. 2-4, Feuilles 7-43, Mém. No. 40 (completion of Mém. de Paléo. No. 26), pp. 44, 46, 1939.

(454) See Eames, F. E., and Cox, L. R., Proc. Malacol. Soc. London, Vol. 32, Pts. 1 and 2, p. 59, 1956.

(455) See Grant, U. S., and Gale, H. R., Mem. San Diego Soc. Nat. Hist., Vol. 1, pl. 9, fig. 1; pl. 10, fig. 6, 1931.

(456) Live specimens of *Pecten subnodosus* were reported recently from off Santa Catalina Island, California, by Turner and Mitchell (Calif. Fish and Game, Vol. 54, No. 1, p. 53, fig. 3, January, 1968).

(457) *Athlopecten* Marwick, Trans. Proc. New Zealand Inst., Vol. 58, Pt. 4, pp. 447, 454, February 28, 1927. "Type: *Pecten athleta* Zittel" [Paläont. von Neu-Seeland, Novara Exped., Geol. Theil., Bd. 1, Abt. 2, p. 49, Taf. 10, fig. 1, 1864.] "Motupipi in der Massacre-Bay, Südinsel."

(458) *Pecten simpsoni* Philippi, Los Fósiles Terciarios i Cuartarios de Chile (Santiago), p. 202, pl. 46, fig. 1, 1887. "Comun en Chiloé." Also "Humñimo"; and "La Mocha, Navidad (raro), Curauma."

(459) See Boreham, A. U. E., "The New Zealand Tertiary genus *Sectipecten* Marwick (Mollusca)," Trans. Roy. Soc. New Zealand, Vol. 88. (quart. issue), Pt. 4, pp. 655-668, pls. 45-49, fig. 1 in text, February, 1961.

(460) Reported recently by Addicott (U.S.G.S., Prof. Paper 524-A, p. A-13, pl. 3, Fig. 8, 1965) from the Pancho Rico Formation, Salinas Valley, California, Pliocene.

(461) *Pallium estrellanum* Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, No. 6, p. 313, December, 1856 (apparently issued early in 1857) "Locality. Estrella valley, Cal. Dr. Newberry."—Arnold, U.S.G.S., Prof. Paper 47, p. 74, pl. 19, figs. 1, 1a; pl. 20, figs. 1, 2, 2a; pl. 21, figs. 1, 1a, 1b, 2, 2a, 2b, 1906 (as *Pecten (Lyropecten) estrellanus*). Late Miocene.

(462) *Pecten (Lyropecten) estrellanus* Conrad var. *terminus* Conrad, Arnold, U.S.G.S., Prof. Paper 47, p. 77, pl. 23, figs. 2, 2a,

1906. "Santa Margarita formation (upper Miocene), Monterey County, Cal." (expl. to plate). Woodring (U.S.G.S., Prof. Paper 190, p. 34, 1938) suggested that the specimen illustrated by Arnold on pl. 19, figs. 1, 1a, is probably referable to *P. e. terminus*.

(463) *Pecten (Lyropecten) estrellanus* Conrad var. *catalinae* Arnold, U.S.G.S., Prof. Paper 47, p. 76, pl. 20, figs. 3, 3a, 4, 1906. "found in a limy matrix near Isthmus, Santa Catalina Island, Los Angeles County." "Upper Miocene."

(464) *Pecten (Lyropecten) gallegosi* E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 434, pl. 29, fig. 1, July 22, 1926. "on shore nine miles north of Bernstein's abalone camp, Cedros Island, Lower California; upper Pliocene."

(465) *Pallium crassicardo* Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, No. 6, p. 313, December, 1856 (apparently issued early in 1857). "Locality. Monterey Co., Cal. A. S. Taylor."—Arnold, U.S.G.S., Prof. Paper 47, p. 71, pl. 16, figs. 1, 1a; pl. 17, figs. 1, 1a, 1b; pl. 18, figs. 1, 2, 2a, 1906. Late Miocene also in early Miocene in southern California.

(466) Fischer, M. P., "Sur l'Anatomie des Hinnites," Jour. de Conchyl., Vol. 10, No. 3 (Ser. 3, Vol. 2), pp. 205-217, pl. 11, 1862. See also Vol. 11, pp. 144-146, 1863.

(467) See Dall, W. H., Bull. U.S. Nat. Mus., Vol. 90, p. 134, 1915.

(468) *Prohinnites* Gillet, Bull. Soc. Hist. Nat. L'yonne, Vol. 75, (II, Sci. Nat.), p. 94, Ann. 1921 (1922). Type designated by Korobkov (in Osnovy Paleontologii. Spravochnik dlia Paleontologov i Geologov SSSR. Molliuski-Pantzirnye, Dvustvorchatye, Lopatonogie. Otvetstvennyi redaktor toma A. G. Eberzin. Izdatel'stvo Akademii Nauk SSSR, Moskva, p. 84, 1960). Type, *Hinnites leymerieri* Deshayes, 1842.

(469) See Rollier, L., Abhandl. Schweiz. Paläo. Gesellsch., Bd. 41, pp. 450-466, 1915.

(470) *Hinnites crassa* Conrad, U.S. Pac. Railroad Survey Expl., Vol. 7, Pt. 2, p. 190, pl. 2, figs. 1, 2, 1856 (1857). "Locality.—Santa Margarita, Salinas Valley."

(471) *Pecten (Chlamys) multirugosus* var. *crassiplicatus* Gale, Trans. San Diego Soc. Nat. Hist., Vol. 5, No. 9, p. 93, February 29, 1928.

(472) Arnold, R., U.S.G.S., Prof. Paper 47, p. 94, pl. 29, fig. 1, 1906. (Figure of Conrad's type of *Hinnites crassa*).

(473) Woodring, W. P., and Stewart, R. B., in Woodring, W. P., Stewart, R. B., and Richards, R. W., U.S.G.S., Prof. Paper 195, p. 70, and list opp. p. 78, pl. 31, figs. 3, 4, 8, 1940 (1941).

(474) *Hinnites benedicti* Adegoke, Univ. Calif. Publ. Geol. Sci., Vol. 80, p. 103, pl. 3, figs. 3, 5, September 25, 1969.

(475) Dollfus, G. F., and Dautzenberg, P., Mém. Soc. Géol. France, Paléo., Mém. No. 27, (Vol. 22, Fasc. 2-4), p. 436, 1920.

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(496) *Lima auaua* Dall, Bartsch, and Rehder, Bernice P. Bishop Mus., Bull. 153, p. 106, pl. 27, figs. 5-8, July 25, 1938. Dredged "in Auaua Channel between Maui and Lanai, in 28-43 fathoms on sand and gravel bottom; bottom temperature, 74.0°F."

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(664) See Oldfield, E., "The functional morphology of *Kellia suborbicularis* (Montagu), *Montacuta ferruginosa* (Montagu) and *M. substriata* (Montagu), (Mollusca, Lamellibranchiata)," Proc. Malacol. Soc. London, Vol. 34, Pt. 5, pp. 255-295, figs. 1-11, August 1961.

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(678) *Rochefortia golischi* Dall, Proc. U.S. Nat. Mus., Vol. 52, No. 2183, p. 411, December 27, 1916. "Off Santa Rosa Island, California, in 13 fathoms."

(679) See MacGinitie, Nettie, Min. Conch. Club South. California, No. 148, p. 6, June-July, 1955.

(680) Valentine, J. W., "Pleistocene Molluscan Notes. I. The Bay Point formation at its type locality," Jour. Paleo., Vol. 33, No. 4, pp. 685-688, 1 fig. in text, 1959. (See p. 687.)

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(890) See Baugh, A. C., "A History of the English Language" (D. Appleton-Century Company, Inc.: New York), p. 21, 1935.

(891) See Jacobs, T. J., Scenes, Incidents and Adventures in the Pacific Ocean, or, the Islands of the Australian Seas, during the cruise of the Clipper Margaret Oakley, under Capt. Benjamin Morrell (Harper & Bros.: New York), pp. 83, 84, 1844. For example, "Pitar Cave."

(892) *Katherinella* Tegland, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 18, No. 10, p. 280, May 8, 1929. "Genotype.—*Callocallista arnoldi* Weaver," Univ. Washington Publ. Geol., Vol. 1, No. 1, p. 40, pl. 2, fig. 13, February, 1916 (as *Callocallista arnoldi*). "in railways cuts on the O. -W. R. R. & N. Co. one fourth mile northwest of Lincoln Creek Station in Section 27, Township 15 North, Range 3 West." "Lowermost Oligocene; *Molopophorous lincolnensis* zone." See also discussion of the genus *Katherinella* by Stenzel, Krause, and Twining (Univ. Texas, Bull. Bur. Econ. Geol., No. 5704, pp. 133-135, 1957) and by Moore, Ellen J. (U.S.G.S., Prof. Paper. 419, pp. 76-77, 1963).

(893) Earlier in this memoir (1944, p. 48) we referred this record to "?*Compsomyax subdiaphana* Carpenter." Whether or not is is referable to that species or the present one is open to question.

(894) *Macrocallista* Meek, Rept. U.S. Geol. Surv. Territories, Vol. 9, p. 179, 1876. Type (by monotypy): *Venus gigantea* Gmelin.

(895) The species described as *Cytherea newcombei* by Merriam from the Sooke formation, probably of early Miocene age, on Vancouver Island, British Columbia, was later referred to *Compsomyax* (as subgenus of *Venerella*) by Weaver (Univ. Washington Publ. Geol., Vol. 5, Pt. 1, p. 193, pl. 42, fig. 17; pl. 43, fig. 9; pl. 45, figs. 6, 8, 15, 17, 18, 1942 (issued Dec. 31, 1943).)

(896) See footnote 892.

(897) See Kobelt, W., Illustr. Conchylienbuch, Bd. 2, p. 339, 1881. "*Murcia* Ad., glatte Arten mit dem Typus *V. pinguis* Chemn." (Syst. Conchyl. -Cab., Bd. 6, p. 355, Tab. 34, figs. 355-357, 1782. "ostindischen Meeren.") [= *Venus opima* Gmelin.] [Some authors have considerd *Venus exalbida* Chemnitz (Syst. Conchyl. Cab., Bd. 11, p. 225, Tab. 202, fig. 1974, 1795. "Sie sey bey den Falklandsinsuln gefunden worden") to be the type as designated by Dall, 1902.]

(898) *Venerella* Cossmann, Ann. Soc. Roy. Malacol. Belg., Vol. 21, p. 105, 1886. Type (designated by Crosse, Journ. de Conchyl. Vol. 34, No. 4, p. 331, 1886): "(type *Venus Hermonvillensis*, Deshayes)" [see Descript. Anim. s. Vert. Bassin Paris, Vol. 1, p. 405, pl. 28, figs. 1-5, 1860. "Hermonville, Damery, Fleury, Boursault." "Calcaire grossier supérieur." Lutétien, Eocene.]

(899) See Etherington, J. T., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 20, No. 5, p. 78, pl. 6, figs. 1, 2, 3, 1931.

(900) See Moore, Ellen J., U.S.G.S., Prof. Paper 419, p. 78, pl. 25, fig. 16, 1963.

(901) See *Marcia (Mercimonia) angustifrons* Conrad, Etherington, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 20, No. 5, p. 81, pl. 6, fig. 4; pl. 7, fig. 3, 1931. Miocene of southwestern Washington. See also Moore, E. J., U.S.G.S., Prof. Paper 419, p. 77, pl. 24, figs. 11-14; pl. 25, figs. 1-3, 5-15; pl. 26, figs. 4, 6, 8, 1963 (as *Katherinella (Katherinella) angustifrons*).

(902) See *Marcia (Mercimonia) angustifrons* var. *brevilineata* Conrad, Etherington, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 20, No. 5, p. 82, pl. 6, figs. 6, 7, 1931. Miocene of southwestern Washington.

(903) See Travis, R. B., Calif. State Div. Min., Bull. 162, p. 21, 1952.

(904) See Woodring, W. P., U.S.G.S., Prof. Paper 222, p. 89, 1950.

(905) *Saxidomus gibbosus* Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 58, pl. 16, figs. 18, 18a, 18b, 1869. "Common in the Pliocene of Eagle Prairie, Humboldt County."—Stewart, Acad. Nat. Sci. Philadelphia, Spec. Publ. 3, p. 224, pl. 14, fig. 6, 1930 [as *Venerella (Compsomyax) subdiaphana*].

(906) *Clementia obliqua* Jukes-Browne, Ann. Mag. Nat. Hist., Ser. 8, Vol. 12, No. 67, p. 60, pl. 1, figs. 1, 2, July, 1913. "Purchased by Mr. J. C. Melvill at the recent sale of Mr. Bülow's collection." "Accompanied by a ticket bearing the inscription '*Caryatis aresta*, Dall and Simpson, Mayaguez, Porto Rico'." See Dall, Nautilus, Vol. 27, No. 9, p. 103, 1914.

(907) *Merretrix iizukai* Yokoyama, Jour. Coll. Sci. Imper. Univ. Tokyo, Vol. 45, No. 5, p. 20, pl. 3, figs. 2, 3, March 21, 1925. Uppermost strata of the Jô-Ban Coalfield in Japan. Cited as Pliocene age but Hatai and Nisiyama, 1952, referred it to the Miocene.

(908) *Clementia (Compsomyax) subdiaphana yazawaensis* Otuka, Bull. Earthquake Res. Inst., Vol. 12, Pt. 3, p. 617, 1934. Lower Kadonosawa series, Miocene.

(909) *Clementia (Compsomyax)* aff. *subdiaphana* Carpenter, Otuka, Bull. Earthquake Res. Inst., Vol. 12, Pt. 3, p. 617, pl. 48, fig. 42, 1934. Shikonai, Miocene.

(910) Römer, E., "Ueber Saxidomus," Malakozool. Blätter, Bd. 8, pp. 63-70, 1861.

(911) *Saxidomus* (?) *noblei* Dickerson, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 8, No. 15, p. 300, pl. 29, fig. 1, December 10, 1914. "University of California Locality 2249, two and three-fourths miles N.80°W of U.S. Geological Survey bench mark (3927 ft.) at Shoemaker, Rock Creek Quadrangle, Los Angeles County, California. Martinez Group."

(912) *Saxidomus popofianus* Dall, Res. Harriman Alaska Exped., Wash. Acad. Sci. (later reissued by the Smithsonian Institution), Vol. 4, p. 115, pl. 10, fig. 4, 1904. "Locality.—Popof Island, 3372." Shumagin Islands, Alaska, "Miocene."

(913) *Venus opaca* Sowerby, Proc. Zool. Soc. London for 1835, p. 42, issued June 1, 1835. "Hab. ad oras Chilenses. (Conception and Maule.)" "Found in sandy mud at low water."—Sowerby, Thes. Conch., Vol. 2, p. 691, pl. 150, fig. 123, 1835 (as *Tapes opaca*).

(914) See *Saxidomus opacus* Sowerby, Carcelles, A. R., and Williamson, S. I., "Catalogo de los Moluscos Marinos de la Provincia Magallanica," Rev. Inst. Nac. Invest. Cienc. Nat. anexo al Mus. Argentino de Cienc. Nat. "Bernardo Rivadavia," Cienc. Zool., Tomo 2, No. 5, p. 341, 1951. "Perú y Chile."

(915) *Eurhomalea* Cossmann, Rev. Crit. de Paléozool., Vol. 24, No. 3, p. 137, July, 1920. New name for *Rhomalea* Jukes-Browne, 1914. ("Type, *Venus rufa*, Lamarck"). Not *Rhomalea* Burmeister, 1839.

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(918) Cited from the "Temblor" by J. P. Smith, 1912; from "lower Miocene beds" by Anderson and Martin, 1914; from "Vaqueros-Temblor" by Nomland, 1917; from the "Topanga formation" by Grant and Quayle in Soper, 1938. Cited with question from the "Temblor Horizon" by Loel and Corey, 1932.

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(920) *Saxidomus vaquerosensis* Arnold, U.S.G.S., Bull. 396, p. 56, pl. 7, fig. 7, 1909 (January 15, 1910). "Locality 4631, *Turritella ocoyana* bed, SE. ¼ NE. ¼ sec. 16, T. 19 S., R. 15 E." "Vaqueros formation, lower Miocene" [Temblor, middle Miocene].

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(927) Parker, P. "Fossil and Recent species of the Pelecypod genera *Chione* and *Securella* from the Pacific Coast," Jour. Paleo., Vol. 23, No. 6, pp. 577-593, pls. 89-95, November, 1949.
(928) *Iliochione* Olsson, Mollusks of the tropical eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 297, March 10, 1961. "Type species, *Venus subrugosa* Sowerby, 1853 (= *Venus subrugosa* Wood)."
(929) See *Chione (C.) californiensis* var. *gealeyi* Parker, Jour. Paleo., Vol. 23, No. 6, p. 580, pl. 90, figs. 7, 10, 1949. "Mission Bay, San Diego, California."
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(938) *Chione elsmerensis* English, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 8, No. 8, p. 214, pl. 23, figs. 1a, 1b, November 7, 1914. "From lower Fernando, Elsmere Cañyon. Univ. Calif. Loc. 1735."
(939) Hertlein, L. G., Stanford Univ. Bull., Ser. 5, No. 78, pp. 84, 85, 1929. San Diego Pliocene.
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(948) *Novathaca* Habe, Gen. Jap. Shells, Pelecypoda No. 2, p. 180, September, 1951. "Type species: *Chione euglypta* Sowerby."
(949) *Tropithaca* Olsson, "Mollusks of the Tropical Eastern Pacific" (Paleo. Res. Inst.: Ithaca, New York), p. 305, March 10, 1961. "Type species *Protothaca grata* (Say)." Illustrated on pl. 53, figs. 2-2b, 7.
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(951) See Gale, H. R., in Preston, H. M., Summ. Oper. Calif. Oil Fields, Vol. 16, no. 4, p. 15, April, May-June, 1931. Woodring, Bramlette, and Kew (1946, p. 27) reported "*Callithaca?* cf. *C. staminea* (Conrad)" from the "middle part of Altamira shale member of Monterey shale," of probable middle Miocene age.
(952) *Protothaca kovatschensis* Ilyina, Trudy Vsesoiuznogo Neftianogo Nauchno-issledovatel'skogo Geologorazvedochnogo Inst. (VNIGRI) (Moskva), Vypusk 202, p. 52, pl. 18, fig. 8, 1963.
(953) See Smith, G. M., "Further observations on the ecology, rate of growth and food supply of some Pacific clams." Trans. Roy. Soc. Canada, Ser. 3, Vol. 27, sec. 5, pp. 229-245, figs. 1-5 in text, 1 map, 1933.
(954) W. O. Addicott and J. G. Vedder (U.S.G.S., Prof. Paper 475C, p. C67, 1963) reported *"Protothaca* cf. *P. tenerrima"* from the Santa Margarita Formation of late Miocene age at Comanche Point, Kern Co., California.
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(957) See Keen, A. M., Veliger, Vol. 4, No. 4, pp. 179-180, 1962.

(958) *Notirus* Finlay, Trans. Proc. New Zealand Inst., Vol. 59, Pt. 2, p. 278, issued August 31, 1928. A new name for *Irona* Finlay, 1926. Not *Irona* Mabille, 1883; not *Irona* Schiödte & Meinert, 1884.

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(960) This species was reported from beds of Pleistocene age at Punta China, Lower California (see Emerson, W. K., Bull. Amer. Mus. Nat. Hist., Vol. 111, Art. 4, p. 339, 1956).

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(965) See Woodring, W. P., in Woodring et al., U.S.G.S., Prof. Paper 195, pp. 94, 95, pl. 24, figs. 4-6, 1940 (1941).

(966) See *Psephidia salmonea* Carpenter, K. V. W. Palmer, Geol. Soc. Amer. Mem. 76, p. 99, pl. 11, figs. 6-12, 1958. "Recent. Catalina Island, California, 30 fathoms (type)."

(967) See Keen, A. M., and Bentson, H., Geol. Soc. Amer., Spec. Papers No. 56, pp. 104, 121, 1944.

(968) *Venus rhysomia* Gabb, Proc. Acad. Nat. Sci. Philadelphia, Vol. 13, p. 369, November, 1861. "From Santa Barbara, Cal. Miocene (?)."

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(975) Hansen, B., "Brood Protection and Sex Ratio of *Transennella tantilla* (Gould), a Pacific Bivalve," Vidensk. Medd. Dansk. Naturhist. København, Bd. 115, pp. 313-324, figs. 1-4, 1953.

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(979) *Petricola pedroana* Conrad, House Document 129, Proj. Vol. 3, 33rd Congress, 1st Session, p. 13, July, 1855. "Occurs with the preceding shell" [that is *Saxicava abrupta*] from "San Pedro. Recent formation."—Conrad, U.S. Pac. Railroad Expl., Vol. 5, p. 324, pl. 3, fig. 24, 1857.

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(988) Hertlein, L. G., and Strong, A. M., "Eastern Pacific Expeditions of the New York Zoological Society. XL. Mollusks from the west coast of Mexico and Central America. Part VII." Zoologica, Vol. 34, Pt. 2, pp. 63-97, pl. 1, August 10, 1949.

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(990) Olsson, A. A., Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), pp. 375-419, 1961.

(991) Boss, K. J., The subfamily Tellinae in the western Atlantic. The genus *Tellina* (Part 1), Johnsonia, Vol. 4, No. 45, pp. 217-272, pls. 127-142, October 31, 1966; the genera *Tellina* (Part II) and *Tellidora*, vol. 4, No. 46, pp. 273-344, pls. 143-163, April 17, 1968.—See also, "Taxonomic revision of the super-specific groups of the Cretaceous and Cenozoic Tellinidae," by F. Afshar, with an appendix by H. A. Rehder. (Geol. Soc. Amer., Mem. 119, pp. I-XI, 1-215, pls. 1-45, 1969) and review by K. J. Boss (Jour. Paleo., Vol. 45, No. 3, pp. 558-560, May, 1971). [Pages 97-107, pls. 42-45, are by H. A. Rehder.]

(992) Not represented in the present collections.

(993) Reported from San Diego Formation but not represented in the present collections.

(994) See Fleming, C. A., Trans. Proc. Roy. Soc. New Zealand, Vol. 79, Pt. 1, p. 134, 1951.

(995) See Burch, J. Q., Min. Conch. Club South. Calif., No. 43, p. 6, January, 1945.

(996) *Tellina nevadensis* Anderson and Martin, Proc. Calif. Acad. Sci., Ser. 4, Vol. 4, p. 61, pl. 2, figs. 3a, 3b, 3c, December 30, 1914. "The type specimen was obtained from the lower Miocene

of Kern River, California, locality 65." Fig. 3b, from Loc. 126 (CAS), "In bed of small creek, near the center of Sec. 34, T. 28 S., R. 15 E., San Luis Obispo County, California."

(997) See Stewart, R. B., U.S.G.S., Prof. Paper 205c, pp. 100, 102, also table 2 (as *Tellina* cf. *idae*), 1946.

(998) See Woodring, W. P., Bull. Amer. Assoc. Petrol. Geol., Vol. 20, No. 2, p. 138, 1936.

(999) See Moore, Ellen J., U.S.G.S., Prof. Paper 419, p. 79, pl. 29, figs. 1-5, 1963.

(1000) *Tellina tenuilineata* Clark, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 11, No. 2, p. 153, pl. 10, figs. 1, 3, 5, July 16, 1918. "Outcrop in bed of creek about one-half mile south and a little west of the town of Walnut Creek." San Lorenzo series, Oligocene.

(1001) *Tellina englishi* Clark, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 8, No. 22, p. 472, pl. 61, figs. 6, 7. August 30, 1915. "From the Upper San Pablo Group on the south side of Mount Diablo, University of California locality 481."

(1002) See Loel, W., and Corey, W. H., Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 22, No. 3, p. 147, 1932.

(1003) *Tellina tenuistriata* Davis, Jour. Geol., Vol. 21, No. 5, p. 457, fig. 7, July-August, 1913. "From the Lower Temblor on the northern San Antonio headwaters, Monterey County, Cal." According to Keen and Bentson, 1938 (p. 116), this locality is in Sec. 21, T. 21 S., R. 5 E., Junipero Serra quadrangle, Monterey Co., California. This species was renamed *Tellina insurana* by G D. Hanna (Proc. Calif. Acad. Sci., Ser. 4, Vol. 13, No. 10, p. 183, March 18, 1924). Also renamed *Tellina davisi* by Salisbury, 1934.

(1004) *Semelangulus* Iredale, Proc. Linn. Soc. New South Wales, Vol. 49, Pt. 3, p. 212, October 24, 1924. "with this species as type," *Tellina tenuilirata* Sowerby, 1867.

(1005) See Kanehara, K., Jap. Jour. Geol. Geogr., Vol. 18, No. 4, p. 138, pl. 16 [not pl. 15 as indicated], fig. 7, December 10, 1942. Setana Series of Hokkaidō.

(1006) See Hatai, K., and Nisiyama, S., Sci. Repts. Tokohu Univ., Sendai, Japan, Second Ser. (Geol.), Spec. Vol. No. 3, p. 141, 1952.

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(1008) See Habe, T., Gen. Jap. Shells, Pelecypoda, No. 3, p. 212, 1952.

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(1010) See Boss, K. J., Johnsonia, Vol. 4, No. 46, pp. 300-327, pls. 152-159, 1968.

(1011) See Eames, F. E., Philos. Trans. Roy. Soc. London, Ser. B, No. 627, Vol. 235, p. 396, 1951.

(1012) *Tellina (Moerella) arenica* Hertlein and Strong, Zoologica, Vol. 34, Pt. 2, p. 68, pl. 1, figs. 5, 11, August 10, 1949. "dredged at station 136-D-20 in Lat. 23°30′N., Long. 109°26′W., in 43 fathoms, mud, on Arena Bank, at the south end of the Gulf of California."

(1013) *Tellina (Peronidia) nitida* Poli, Cossmann and Peyrot, Act. Soc. Linn. Bordeaux, Vol. 64 (Conch. Néog. de l'Aquitaine, Tome 1, Livr. 2), p. 244, pl. 9, figs. 6, 7, 1911.

(1014) *Tellina (Peronidia) santarosae* Dall, Proc. U.S. Nat. Mus., Vol. 23, No. 1210, p. 321, pl. 3, fig. 6; pl. 4, figs. 1, 2, November 14, 1900. "Collected at Santa Rosa Island, of the Santa Barbara group, California, by Stephen Bowers."

(1015) See *Tellina (Peronidia) bodegensis* Hinds n. subspecies?, Clark and Arnold, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 5, p. 149, pl. 22, figs. 7, 8, November 6, 1923. Loc. 231 (CAS), "In the sea cliffs east of the mouth of Kirby Creek, 6 miles west of Sooke, Vancouver Island."

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(1039) *Macoma aomoriensis* Nomura, Saito Ho-On Kai Mus., Res. Bull. Vol. 6, p. 63, pl. 4 (3), figs. 3, 4, 5, September, 1935. Northeast Honsyû, Japan, early Miocene.

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(1041) Slodkewitsch, W. S., Paleo. of USSR (Acad. Sci. USSR), Vol. 10, Pt. 3, Fasc. 18, p. 460, Fasc. 19, p. 170, pl. 95, figs. 8, 8a, 9, 1938. Kavrana series. Kamtschatka, Pliocene.

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(1044) See Berry, S. S., Jour. Conch., Vol. 24, No. 3, p. 83, 1956. Reported from Punta Peñasco, Sonora, Mexico, by Lowe, 1935.

(1045) *Macoma (Rexithaerus) indentata flagleri* Etherington, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 20, No. 5, p. 85, pl. 10, figs. 3, 4, May 20, 1931. From U.C. Loc. 9017 [According to Weaver, 1943, p. 211, the type is from "cut of abandoned spur of Clemons logging road one-fourth mile north of main line in the first large cut in Section 23, T. 17 N., R. 7 W."]

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(1048) *Macoma moliniana* Dall, U.S.G.S., Prof. Paper 59, p. 128, pl. 14, fig. 12, April 2, 1909. "Collected from the Oligocene (?) sandstones at Millers Beach, by W. H. Dall."

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(1050) See *Macoma indentata* Carpenter, Simonova, Trans. Geol. Oil Inst., New Ser. Fasc. 18, p. 46, pl. 20, figs. 4, 5, 1941.

(1051) See *Macoma* aff. *indentata* Carpenter subsp. *tenuirostris* Dall, Faustman, Univ. Calif. Publ. Geol. Sci., Vol. 41, No. 2, p. 122, pl. 1, fig. 12, 1964.

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(1055) *Polymetis* A. E. Salisbury, Proc. Malacol. Soc. London, Vol. 18, Pt. 5, p. 255, July 15, 1929. "I therefore propose the name *Polymetis*, with type *meyeri*, Dkr., for the group in question." Not *Polymetis* Walsingham, 1903. Insecta.

(1056) *Apolymetis* A. E. Salisbury, Proc. Malacol. Soc. London, Vol. 18, Pt. 6, p. 258, November, 1929. A new name for *Polymetis* Salisbury, 1929, (not *Polymetis* Walsingham, 1903), "with the same type, *Tellina meyeri*, Philippi."

(1057) *Hemimetis* Thiele, Handbuch der Systematischen Weichtierkunde, Bd. 2, Teil 3, p. 915, 1934. Sole species, "*A. (H.) plicata* Valenciennes."

(1058) *Psammotreta* Dall, Proc. U.S. Nat. Mus., Vol. 23, No. 1210, p. 292, November 14, 1900. "Type, *Tellina aurora* Hanley."

(1059) See *Apolymetis* cf. *A. sespeensis* (Loel and Corey), Weaver and Kleinpell, Univ. Calif. Publ. Geol. Sci., Vol. 43, p. 207, pl. 38, fig. 2, March 28, 1963. "Undifferentiated Gaviota formation."

(1060) See *Macoma constricta* Bruguière, M. Smith, East Coast Marine Shells, Ed. 3, (Edwards Bros.: Ann Arbor, Michigan). p. 59, pl. 2, fig. 9, 1945. North Carolina to Brazil, Recent.

(1061) *Lutricola cognata* Pilsbry and Vanatta, Proc. Washington Acad. Sci., Vol. 4, p. 556, pl. 35, fig. 5, September 30, 1902. "From Tagus Cove, Albemarle." Galápagos Islands.

(1062) *Apolymetis clarki* Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 90. pl. 24, fig. 12; pl. 25, fig. 14, August 10, 1950. Loc. A-3582 = Pleistocene, Santa Inez Bay, Lower California. From 20-foot terrace level extending from loc. A-3581 to beach.

(1063) See discussion by Hertlein, L. G., and Strong, A. M., Zoologica, Vol. 34, Pt. 2, p. 93-94, August 10, 1949.

(1064) See *Metis alta* Conrad, Khomenko, Trans. Geol. Oil Inst., Ser. A, Fasc. 103, p. 78, pl. 14, fig. 1, 1938. Schmidt Peninsula, Kamtschatka. "Machigar section."

(1065) Keen, A. M., Veliger, Vol. 8, No. 3, p. 170, January 1, 1966.

(1066) See Deshayes, G. P., Proc. Zool. Soc. London for 1854, p. 354, issued May 16, 1855.

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(1068) See Yonge, C. M., Philos. Trans. Roy. Soc. London, Ser. B, Biol. Sci., No. 609, Vol. 234, p. 35, September, 1949.

(1069) See Lamy, E., "Révision des Scrobiculariidae vivants du Muséum d'Histoire Naturelle de Paris," Jour. de Conchyl., Vol. 61, No. 3, pp. 243-368, pl. 8, 18 figs. in text, March, 1914.

(1070) See Dall, W. H., "Notes on the Semelidae of the West Coast of America, including some new species," Proc. Acad. Nat. Sci. Philadelphia, Vol. 67, pp. 25-28, March 2, 1915.

(1071) See Hertlein, L. G., and Strong, A. M., "Eastern Pacific Expeditions of the New York Zoological Society. XLI. Mollusks from the west coast of Mexico and Central America. Part VIII," Zoologica, Vol. 34, Pt. 4, pp. 239-258, pl. 1, December 30, 1949. (*Semele*, pp. 239-249).

(1072) See Keen, A. M., Sea Shells of Tropical West America (Stanford Univ. Press: Stanford, California), pp. 194-202, 1958.

(1073) See Olsson, A. A., Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), pp. 358-375, 1961.

(1074) *Cumingia? antiquata* Philippi, Los Fósiles Terciarios I Cuartarios de Chile, p. 151, pl. 23, fig. 10, 1887. "Cerca de Levu," Chile.

(1075) See von Ihering, H., An. Mus. Nac. Buenos Aires, Ser. 3, Vol. 7, p. 316, 1907.

(1076) Deshayes, M., "Note sur l'animal des Cumingia," Jour. de Conchyl. Vol. 5, pp. 278-282, 1856.

(1077) Grave, B. H. "The Natural History of *Cumingia tellinoides*," Biol. Bull., Vol. 53, No. 3, pp. 208-219, 1927.

(1078) See Lamy, E., Jour. de Conchyl., Vol. 61, No. 3, pp. 306-314, 2 figs., 1914.

(1079) See Strong, A. M., in Burch, J. Q., Min. Conch. Club South. California, No. 43, p. 19, January, 1945.

(1080) *Cumingia lamellosa* Sowerby, Proc. Zool. Soc. London for 1833, p. 34, issued May 17, 1833. "Hab. prope littora Oceani

Pacifici." "Found at Payta in hard clay at low water; and at Panama in deep water."–Sowerby, Reeve's Conch. Icon., Vol. 19, *Cumingia*, species 5, pl. 1, fig. 5, 1873. "Hab. Chile."–Hertlein and Strong, Zoologica, Vol. 34, Pt. 4, p. 250, 1949. "San Martin Island, Lower California, to the Gulf of California and south to Paita, Peru."–Olsson, Moll. Trop. East. Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 371, pl. 66, figs. 10, 10a; pl. 67, figs. 3, 3a, 1961. "Gulf of California to northern Peru."

(1081) *Thyella lamellosa* H. Adams, Proc. Zool. Soc. London for 1873, p. 208, pl. 23, fig. 15. "Hab. Mauritius (coll. H. Ad.)."

(1082) See Yonge, C. M., Phil. Trans. Roy. Soc. London, Ser. B, Biol. Sci., No. 609, Vol. 234, pp. 38-40, September, 1949.

(1083) See Chavan, A., Bull. Soc. Géol. France, Ser. 5, Vol. 6, Nos. 6, 7, 8, pp. 447-450, 1936. See also Bull. Inst. Roy. Sci. Nat. Belgique, Vol. 36, No. 11, pp. 9-10, 1950.

(1084) See Hertlein, L. G., and Strong, A. M., Zoologica, Vol. 34, Pt. 4, pp. 251-258, pl. 1, December 30, 1949.

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(1086) See Olsson, A. A., Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), pp. 336-347, 1961.

(1087) See *Notodonax* Feruglio, Mem. Inst. Geol. Univ. Padova, Vol. 11, No. 3, p. 125, 1936. Sole species, *Donax (Notodonax) anna-eugeniae* Feruglio.

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Eodonax Cox (Ann. Mag. Nat. Hist., Ser. 10, Vol. 3, No. 18, p. 584, June, 1929, type, *Eodonax dukei* Morris and Lycett, late Jurassic), is a member of the family Tancrediidae.

(1089) See *Donax gracilis* Hanley, Hertlein and Strong, Zoologica, Vol. 34, Pt. 4, p. 253, pl. 1, figs. 4, 6, 1949.

(1090) Fitch, J. E., State Calif. Dept. Fish Game, Mar. Fish. Branch, Fish Bull. No. 90, p. 85, fig. 51, 1953.

(1091) Coe, W. R., "Ecology of the Bean Clam *Donax gouldi* on the coast of southern California," Ecol., Vol. 36, No. 3, pp. 512-514, figs. 1 and 2, 1955. See also, Univ. California Scripps Inst. Oceanogr., Contrib. for 1955, No. 787, pp. 605-608.

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(1097) Dodge, H., Bull. Amer. Mus. Nat. Hist., Vol. 100, Art. 1, pp. 42-43, 1952.

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(1126) Dall, W. H., "Synopsis of the Solenidae of North America and the Antilles," Proc. U.S. Nat. Mus., Vol. 22, No. 1185, pp. 107-112, October 9, 1899.

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Res. Bull., No. 6, p. 64, pl. 7 (6), fig. 3, September, 1935. "Tanozawa (near the railroad station) Ôdose-mura." Nisi-Tugaru district, Aomori-ken, Northeast Honsyû, Japan, Lower Miocene.

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(1159) Not represented in the present collection.

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(1163) See Weaver, C. E., Univ. Washington Publ. Geol., Vol. 5, Part 1, p. 239, December, 1942 (issued December 31, 1943). See discussion by Ellen J. Moore, U.S.G.S., Prof. Paper 419, p. 83, 1963.

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(1165) See Dall, W. H., U.S. Nat. Mus., Bull. 112, p. 52, 1921.

(1166) *Hemimactra* Swainson, Treatise on Malacol., p. 369, 1840. Species cited, "*H. gigantea* Lam. v. 472, No. 1, *grandis* Sw. Sp. Nov." Type designated by Gray (Proc. Zool. Soc. London for 1847, p. 185): "*M. gigantea*." This is believed to be identical with *Mactra solidissima* Chemnitz, 1788, the hinge of which was well illustrated by Lamy (Jour. de Conchyl., Vol. 63, No. 4, p. 292, 1918).

(1167) See Woodring, W. P., in Woodring, W. P., and Bramlette, M. N., U.S.G.S., Prof. Paper 222, p. 88, 1950.
(1168) *Spisula catilliformis* Conrad, var. *alcatrazensis* Arnold, Smithsonian Miscell. Col. (Quart. Issue), Vol. 50, Pt. 4, No. 1781, p. 437 (separate p. 19), pl. 56, fig. 6, December 13, 1907. "Alcatraz asphalt mine, near Sisquoc, Santa Barbara County, California; locality No. 4471." "Fernando formation, lower Pliocene portion."
(1169) Addicott cited records of *Spisula falcata* from the Tehana Member, lower portion of the Purisima Formation in Portola Valley in San Mateo County, California (Proc. Calif. Acad. Sci., Ser. 4, Vol. 37, No. 3, p. 83, 1969).
(1170) *Spisula falcata brioniana* Trask, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 13, No. 5, p. 152, pl. 4, figs. 2a, 2b, May 10, 1922. "U.C. loc. no. 3522," 283 mm. east and 210 mm. south of the northwest corner of the Concord quadrangle topographic sheet, California. According to Keen and Bentson (Geol. Soc. Amer., Spec. Papers 56, p. 109, 1944) this locality is "N ½ 1, T 1 S, R. 2 W," Contra Costa Co., California.
(1171) *Spissula dolabriformis* Conrad, Amer. Jour. Conch., Vol. 3, Pt. 2, p. 193, September 5, 1867. "Inhabits Panama." (Cited under "*Spisula*" in Vol. 3, Pt. 3, Ap., p. 44, 1868).–Conrad, Amer. Jour. Conch., Vol. 5, Pt. 2, p. 108, pl. 12, fig. 1, 1869. [Smaller figure only.]–T. A. Burch, Min. Conch. Club South. California, No. 49, p. 50, pl. 3, figs. 32 and 33 (type), 40, June, 1945 (as *Spisula dolabriformis*).–Olsson, Mollusks of the tropical eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 325, pl. 57, figs. 1, 1a; pl. 58, figs. 4, 4a, 1961 (as *Mactra (Mactromeris) dolabriformis*).
(1172) The reported occurrence of this species at Corinto, Nicaragua, by Eyerdam was based upon one specimen (see Pacific Northwest Shell News, Vol. 2, No. 4, p. 55, July, 1962).
(1173) Record from this locality was based upon a right valve 42 mm. long (ventral portion imperfect), from the Mackenzie Gordon collection now in the California Academy of Sciences.
(1174) *Spisula cameronis* Dall, West Amer. Sci., Vol. 19, No. 3, p. 22, June 15, 1921. "Pliocene (or early Pleistocene) of San Quentin Bay, Lower California."–Dall, Proc. U.S. Nat. Mus., Vol. 66, Art. 17, No. 2554, p. 26, pl. 10, fig. 2; pl. 11, fig. 4, 1925. "Pliocene (?) of San Quentin Bay, Lower California."
(1175) *Spisula (Hemimactra) mossbeachensis* Glen, Univ. Calif. Publ. Geol. Sci., Vol. 36, No. 2, p. 175, pl. 15, fig. 8; pl. 16, fig. 1, November 23, 1959. " 'Merced' formation of Pillar Point," Pliocene.
(1176) *Spisula longa* Dall, West Amer. Sci., Vol. 19, No. 3, p. 22, June 15, 1921. "Pliocene (or early Pleistocene) of San Quentin Bay, Lower California."–Dall, Proc. U.S. Nat Mus., Vol. 66, Art. 17, No. 2554, p. 27, pl. 10, fig. 1; pl. 11, fig. 3, 1925. "Pliocene (?) of San Quentin Bay, Lower California."
(1177) *Spisula (Mactromeris) hemphilli* var. *orcutti* Manger, Johns Hopkins Univ. Studies in Geol., No. 11, p. 301, pl. 21, Figs. 5, 6, 1934. "San Quentin Bay," Lower California, Pleistocene.
(1178) For references to this species see footnote 1171.
(1179) *Spisula strongi* T. A. Burch, Min. Conch. Club South. Calif., No. 49, p. 50, pl. 3, figs. 35-39, June, 1945. "Newport Bay, Calif." Recent.
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(1181) *Spisula sisquocensis* Arnold, Smithsonian Misc. Coll. (Quarterly Issue), Vol. 50, Pt. 4, No. 1781, p. 437 (separate p. 19), pl. 56, fig. 1, December 13, 1907. "Alcatraz asphalt mine, near Sisquoc, Santa Barbara County, California; locality No. 4471. "Fernando formation, lower Pliocene portion."
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(1183) See Burch, T., Min. Conch. Club South. Calif., No. 44, pp. 8, 17, 18, 21-22, February, 1945.
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(1185) *Spisula strongi* T. Burch, Min. Conch. Club South. California, No. 49, p. 50, pl. 3, figs. 35-39, June, 1945. "The type specimen was collected from Newport Bay, Calif. by Mr. A. M. Strong."
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(1331) Not represented in the present collection.
(1332) See Faustman, W. F., Univ. Calif. Publ. Geol. Sci., Vol. 41, No. 2, p. 117, 1964.
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(1338) See Iredale, T., Rec. Australian Mus., Vol. 17, No. 9, p. 387, June 27, 1930.
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(1340) *Periploma teevani* Hertlein and Strong, Zoologica, Vol. 31, Pt. 3, No. 8, p. 95, pl. 1, figs. 2 and 6, December 5, 1946. "Lat. 15°44'N., Long. 96°05'W., Tangola-Tangola Bay, Oaxaca, Mexico, dredged in 30 fathoms (55 meters), mud."
(1341) *Periploma venezuelana wiedenmayeri* H. K. Hodson, Bull. Amer. Paleo., Vol. 16, No. 59, p. 7, pl. 1, figs. 3, 5, 7, October 1, 1931. "2 kilometers south and 600 meters east of La Compana, District of Democracia, State of Falcón. (La Compana is 11.5 kilometers east and 2 kilometers south of Urumaco.)" Venezuela, lower middle Miocene.
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(1343) *Cochlodesma leana floridana* Mansfield, Jour. Paleo., Vol. 11, No. 7, p. 611, pl. 85, figs. 12, 14, October, 1937. "Lower part of the upper Miocene bed, *Ecphora* zone, at Jackson Bluff, Leon County, Florida."
(1344) *Cochlodesma* Couthouy, Boston Jour. Nat. Hist., Vol. 2, p. 170, 1839. Type (designated by Gray, Proc. Zool. Soc. London for 1847, pp. 190-191): "*Mya praetenuis*" [Pulteney, Catalogues of the Birds, Shells, . . . , Plants, . . . Dorsetshire, ed. 1, p. 28, 1799. "Petiver received his shell from Poole, where I have found it on the sands, in the harbour, and on the North shore, near Brownsea Isle, and once a few valves on the shore between Waymouth and Portland." Also Illustrated by Soot-Ryen, Trømso Mus. Arsheft. (Naturhist. Avd. No. 17), Vol. 61, No. 1, p. 34, pl. 5, figs. 3, 4; pl. 7, fig. 5, pl. 10, fig. 12, 1941 (as *Cochlodesma (Bontaea) praetenue*). Norway to France, Recent.]

Vokes (Jour. Paleo., Vol. 30, No. 3, p. 764, May, 1956) pointed out that *Bontaea* (Leach MS) Brown, 1844, and *Galaxura* Leach, 1852, are synonyms of *Cochlodesma*. *Aperiploma* Habe (Gen. Jap. Shells, Pelecypoda, No. 3, p. 265, 1952), with the type species *Cochlodesma leana* "Conthouy" [= *Anatina leana* Conrad (Jour. Acad. Nat. Sci. Philadelphia, Vol. 6, p. 263, pl. 11, fig. 11, April, 1831; also illustrated by Gould (Rept. Invert. Massachusetts, Boston, edit. 2, by W. G. Binney, p. 68, fig. 383, 1870); see synonyms by Lamy (Jour. de Conchyl., Vol. 75, No. 4, p. 318, 1931)] was proposed as a subgenus of *Periploma*.
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(1348) Allen, J. A., "The British Species of *Thracia* (Eulamellibranchia)," Jour. Mar. Biol. Assoc. U.K., Vol. 41, No. 3, pp. 723-735, pl. 1, text-figs. 1-5, October, 1961.
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(1351) See Deshayes, G. P., Dict. Class. Hist. Nat., Vol. 16, p. 235, 1830. ". . . *Thracia pubescens*. Cette coquille n'est autre que le *Mya pubescens* de Linné. . . . nous avons su que cette belle espèce était devenue le type d'un nouveau genre du Zoologiste anglais."
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(1353) *Thracia trapezoides* Conrad, U.S. Explor. Exped. (Wilkes), Geol., Vol. 10, p. 723, Atlas, pl. 17, fig. 6a, 1849. "Astoria, Oregon." [Miocene]—Dall, U.S.G.S., Prof. Paper 59, p. 135, pl. 2, fig. 14; pl. 13, fig. 7, 1909 (as *Thracia trapezoidea*). Astoria, Oregon, Miocene.—Weaver, Univ. Washington Publ. Geol., Vol. 5, p. 117, pl. 25, fig. 7; pl. 29, fig 5; pl. 104, fig. 11 (holotype), 1942 (issued December 31, 1943.)—Moore, Ellen J., U.S.G.S., Prof. Paper 419, p. 84, pl. 26, fig. 3; pl. 31, fig. 6 (holotype), 1963.
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(1357) *Thracia formosa* Nomland, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 10, No. 14, p. 234, pl. 9, figs. 4, 4a, April 19, 1917. Loc. 2991 (UC), "Near center of SE ¼ Sec. 17, T. 22 S, R. 16 E. On top of ridge south of road. *Pecten coalingensis* zone."
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(1370) *Dermatomya (tenuiconcha* Dall, 1913, var.?*) sagamiensis* Okutani, Bull. Tokai Reg. Fish. Res. Lab., Tokyo, Japan, No. 32, p. 32, pl. 3, fig. 3; pl. 5, figs. 8, 8a, January, 1962. Type locality: "Sagami Bay, 700-750 m."

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(1373) Kuroda, T., "Studies on Japanese species of *Cuspidaria*," Jap. Jour. Malacol., Vol. 15, Nos. 1-4, pp. 1-28, pls. 1 and 2, 1948.

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(1376) See Vedder, J. G., U.S.G.S., Prof. Paper 400 B, p. B326, 1960.

(1377) See Simonova, A. A., Trans. Geol. Oil Inst., New Ser., Fasc. 18, p. 29, pl. 10, fig. 1, 1941.

(1378) Kuroda, T., "On the Verticordiidae from Japan," Venus, Vol. 17, No. 1, pp. 6-16, pl. 1 (figs. 1-18), and figs. 19, 20 (p. 15), July, 1952.

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(1380) See Soot-Ryen, T., Sarsia, No. 24, pp. 15-27, pls. 1-3, figs. 11-13 in text, April, 1966.

(1381) See *Verticordia granulosa* Ravn, Kon. Dan. Vidensk. Selskab., Biol. Skr., Bd. 1, Nr. 1, p. 39, pl. 1, figs. 12 a-b, 13, 14 a-b, 1939. "Paléocène de Copenhague."

(1382) Fischer, P., "Note sur les genres *Hippagus* et *Verticordia*," Jour. de Conchyl., Vol. 8 (2nd Ser., Vol. 4), pp. 295-300, 1860; also Vol. 10, pp. 378-381, 1862.

(1383) *Verticordia aequicostata* Howard, Nautilus, Vol. 63, No. 4, p. 109, pl. 7, 2 figs., April, 1950. Type "from north of Angel La Guardia Island, 90 fathoms." [Gulf of California.]

(1384) *Verticordia perplicata* Dall, Proc. U.S. Nat. Mus., Vol. 12, No. 773, p. 278, pl. 8, fig. 1, issued March 7, 1890. "Hab.–U.S. Fish Commission Station 2807, in 812 fathoms, mud, near the Galápagos Islands; bottom temperature 38°.4 F."

LIST OF LOCALITIES

CALIFORNIA ACADEMY OF SCIENCES

104. Sea cliff about three miles south of La Jolla, Pacific Beach.
105. Along the west margin of the peninsula which extends into False Bay from the north, Pacific Beach, San Diego.
547. Fossils from beach cliff north of Pacific Beach, San Diego.
957. Pacific Beach, upper 5 to 15 feet beneath unconformably overlying Pleistocene beds.
1129. Reynard Way off State Street, San Diego.
1130. San Diego, unlocalized.
1132. Upper beds in Pliocene section at Pacific Beach. [= SD Loc. 34]
1135. Between Reynard Way and Union Street, San Diego.
1136. South of organ in Balboa Park, San Diego.
1137. 31st Street and Logan Avenue, San Diego.
1138. Pacific Beach, San Diego.
1140. Sweetwater Hills, one half mile west of water pipe house.
1141. 32nd and Woolman, San Diego.
1155. Beds from top of hill to oyster bed at Locality 1154. Highest beds on hill west of dike. Top of ridge above San Augustine Canyon east side. About 9.6 Kilometers (6 miles) south of ranch house. Santa Rosa Island, California.
1176. Fossiliferous beds exposed on road going up hill 0.3 mile (.48 kilometer) north of San Diego well which was located at foot of Ash Street in valley of canyon below Russ School.
1177. Road cut on west side of hill just east of corner of Haines Street and Tourmaline Avenue, Pacific Beach.
1178. At foot of Diamond Street, Pacific Beach. [= SD Loc. 21]
1179. Upper beds of lower portion of Pliocene section exposed at Pacific Beach.
1181. South slope of Mt. Soledad, above middle part of gulch, altitude about 140 feet, about 1/3 mile (first gulch) west of Rose Canyon. [= SD Loc. 4 and 80]
1182. At elevation of about 90 feet in first gulch, 300-400 yards west of mouth of Rose Canyon, south slope of Mt. Soledad.
1183. Eagle Street just north of Quince Street, just east of Reynard Way, San Diego.
1186. Cliffs on east side of Reynard Way near mouth of canyon, 100 yards off main highway, where brickyard was located. [= SD Loc. 27]
1199. Pacific Beach, San Diego.
1399. 100 to 200 yards south of Eocene-Pliocene contact at Pacific Beach.
1400. Upper beds in Pliocene section at Pacific Beach, near Loc. 957 (CAS). [= SD Loc. 150]
1401. First canyon west of Rose Canyon on south slope of Mt. Soledad.
1402. About 100 m south of the west end of Laurel Street bridge across Cabrillo Canyon, on point between Cabrillo Canyon and a gulch running into the canyon, Balboa Park, San Diego. [= SD Loc. 29]
1404. Southeast corner of India and Upas Streets, San Diego. [= SD Loc. 75]
1413. Beds of lower portion of Pliocene section exposed at Pacific Beach.
1414. Beds in middle portion of Pliocene section exposed at Pacific Beach.
1415. Road cut north of bridge over 26th Street canyon, San Diego.
1418. Northeast corner of Spruce and Thorn streets, San Diego. [= SD Loc. 38 and 79]
1419. Northeast corner of India and Thorn streets, San Diego. [= SD Loc. 34]
2015. Pacific Beach, San Diego.
2020. Pacific Beach, San Diego.
2028. Cliffs north of Pacific Beach, San Diego.
12051. San Diego, unlocalized.
12053. Pacific Beach, San Diego.
12078. San Diego well.
12096. San Diego, Calif. (H. Hemphill) ["apparently from well in Balboa Park, San Diego, Cal."].
12099. Well at San Diego.
12107. Well at San Diego in Balboa Park.
12142. San Diego, unlocalized.
12145. Cedros Island.
12147. San Diego, unlocalized.
12149. Pacific Beach, San Diego.
28158. Pacific Beach.
28159. Small ravine at Pacific Beach.
28453. Silty beds in road bank on canyon road in southwest corner of Balboa Park, San Diego.
28454. Cut in strata at stairway to concession, Balboa Park, San Diego.
28644. Pacific Beach, San Diego.
28880. On Market Street, 1/10 mile east of Euclid Street, in Las Chollas Valley, San Diego. [= SD Loc. 408]
28882. Small canyon on south slope of Mt. Soledad.
28884. Embankment on Windsor Drive where Tourmaline Avenue would intersect if projected, Pacific Beach.
28885. Small ravine in west face of terrace 250 yards north of Mexican Boundary and 3/4 mile from the coast (a little north of south edge of willow patch and a farm road). [= SD Loc. 416; UCLA 310]
28886. 200 yards south of end of Law Street, if projected, Pacific Beach.
28887. *Dosinia* beds, 1/5 mile south of the Ford Building at bottom of Cabrillo Canyon, San Diego.
28888. Fossiliferous strata 10 to 20 feet above the road in the first terrace in prominent cut on west side of the road at the lower entrance to Mount

Hope Cemetery, between Imperial Avenue and the old Cuyamaca railroad (= 36th Street). [= SD Loc. 409; UCLA Loc. 303]

28889. Fifth ravine north (about 1/4 mile) of the Mexican boundary, at west face of terrace 3/4 mile east of coast, the ravine debouching near the north end of a willow patch. [= SD Loc. 417]

28890. 0.4 mile north of Broadway on Fairmount Avenue, San Diego.

28891. West shore of Bay Point near Fontera and La Mancha streets, San Diego.

28892. 200 feet north of Mexican boundary and 3/4 mile east of coast, in east-west ravine, tributary to a larger south north ravine at right angle, in first terrace above Tiajuana River plain. [= UCLA Loc. 294; SD Loc. 331]

28893. Corner of India and Upas streets, San Diego.

28894. In canyon below ranch one half mile north up Aquamar Lane from Foothill Boulevard, Pacific Beach.

31320. Market Street extension at 54th Street, San Diego.

31356. Pacific Beach, San Diego.

33334. 100-foot bluff with fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego.

34221. Encinitas, San Diego County.

35025. Pacific Beach, San Diego.

36384. About two feet above top of basal conglomerate of San Diego Fm. in road cut on east side of Cabrillo Freeway at elevation of about 225 feet, nearly opposite Mercy Hospital, San Diego

36599. Intersection of Wabash, Imperial and side street entering on arroyo about 1000 feet west of Lucky Lager warehouse, San Diego. Reworked fossils in whitish sand.

SAN DIEGO SOCIETY OF NATURAL HISTORY

2. Northeast side of gulch at elevation of 90 feet, 300 to 400 yards west of Rose Canyon, on south slope of Mt. Soledad.

4. Gulch no. 2, a little above its middle, at an elevation of about 140 feet, about 1/3 mile from Rose Canyon highway, south slope of Mt. Soledad. [= SD Loc. 80; CAS Loc. 1181]

5. Second gulch west of Rose Canyon highway, south slope of Mt. Soledad, 30 feet higher than Loc. 4 (SD).

10. Fossil Canyon, just north of Telegraph Canyon, about 1/2 mile east of Chula Vista.

17. About 3/8 mile up side canyon draining into long canyon, under the words "La Nacion" on U.S.G.S. topog. map of San Diego quad.

20. Approximately at point of intersection of 11th and Fir streets, if projected, along old road leading up south ridge of mesa from canyon bottom, Balboa Park, San Diego.

21. West end of Diamond Street, Pacific Beach. [= CAS Loc. 1178]

23. West side of hill just east of corner of Haines and Tourmaline streets, Pacific Beach.

24. About 150 feet south of Eocene-Pliocene contact, 3/4 miles north of Garnet Street Pier, Pacific Beach.

25. In bank at side of road just east and north below Mercy Hospital, on Sixth Street grade leading down into Mission Valley, San Diego.

27. Cliffs on east side of Reynard Way near mouth of canyon, 100 yards off main highway near old brickyard. [= CAS Loc. 1186]

29. On end of point between Cabrillo Canyon and a gulch about 100 m south of the west end of Laurel Street bridge across Cabrillo Canyon in Balboa Park. [= CAS Loc. 1402]

34. Northeast corner of India and Thorn streets, San Diego. [= CAS Loc. 1132 and 1419]

36. Columbia and State streets, San Diego.

37. Pacific Beach, unlocalized.

38. Northeast corner of India and Spruce streets, San Diego. [= CAS Loc. 1418]

54. India Street near Spruce Street, San Diego.

61. About 2 miles south of Ocean Beach and about 2/3 of a mile north of the military reservation, San Diego.

70. Balboa Park, San Diego.

75. Southeast corner of India and Upas streets, San Diego. [= CAS Loc. 1404]

79. Northeast corner of India and Spruce streets, San Diego. [= CAS Loc. 1418]

80. A little above middle part of a gulch 1/3 of a mile west of Rose Canyon, south slope of Mt. Soledad [= CAS Loc. 1181 and 1401]

81. Under bridge 1/2 mile east of Mission Cliffs Gardens, San Diego.

83. Reynard Way, San Diego.

88. South slope of Mt. Soledad.

150. Pacific Beach. [= CAS Loc. 1400]

302. San Diego, unlocalized.

331. Exposure in east-west ravine tributary to a larger south-north ravine at right angle, in first terrace above Tiajuana River plain, 200 feet north of Mexican boundary and 3/4 mile from the coast. [= CAS Loc. 28892]

365. Second ravine north of Rose Canyon, south slope of Mt. Soledad.

402. Lowest *Pecten healeyi* bed exposed just south of ravine which is just south of Eocene-Pliocene contact, Pacific Beach.

403. Including and above *Pecten healeyi* bed at Loc. 402 (SD), Pacific Beach.

404. *Pecten invalidus* bed at second ravine south of Eocene-Pliocene contact, Pacific Beach.

320A. In chalky-white marl-like sediment 11 feet thick, 110 feet back of house at Loc. 320 (LAM).
323. Under bridge between Fifth Street and the Radio Station, about 160 feet from the fence and about 350 feet from the Radio Station, San Diego.
1141. 32nd and Woolman Avenue, San Diego.
1155. Between Reynard Way and Union Street, San Diego.
1176. 0.3 mile north of San Diego well on road up hill.
A1323. Fossil Canyon east of Chula Vista.
A2081. Pacific Beach.
P87. Upas and India streets, San Diego.
P87. No.8325. 32nd Avenue and Woolman Street, San Diego.
P87. No.S8339. Pacific Beach
P87. No.S8443. Southwest of the end of the bridge over Cabrillo Canyon, Balboa Park, San Diego.
P87. No.S8442. San Diego, unlocalized.

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294. 200 feet north of Mexican boundary in east-west ravine tributary to larger south-north ravine in first terrace above Tiajuana River plain, three fourths mile east from the coast. [= SD Loc. 331; CAS Loc. 28892]
295. Second ravine west of mouth of Rose Canyon, south slope of Mt. Soledad. [= SD Loc. 365]
296. Street cut on northwest side of Fairmount, 0.4 mile north of intersection with Broadway, San Diego.
298. Pacific Beach, San Diego. [= SD Loc. 402]
299. *Pecten healeyi* bed and above it, commencing at second ravine south of Pliocene-Eocene contact, Pacific Beach [= SD Loc. 404]
300. Coarse sandstone containing *Chlamys invalida*, extending south from second ravine south of Pliocene-Eocene contact, Pacific Beach. [= SD Loc. 403]
301. Hard coarse sandstone bed exposure beginning at third ravine south Eocene-Pliocene contact, tact, Pacific Beach.
302. Road cut 0.1 mile east of Euclid Avenue on north side of Market Street, San Diego. [= SD Loc. 408; CAS Loc. 28880]
303. Between Imperial Avenue and old Cuyamaca railroad (36th Street), San Diego. [= SD Loc. 409; CAS Loc. 28888]
305. "Barnacle Reef" in coquina sandstone just below bottom of Sweitzer conglomerate, on spur of mesa across Las Chollas Valley.
306. Float at base of railroad cut between Las Chollas Valley and 32nd and Greeley streets, San Diego. [= SD Loc. 412]
307. About a block above Market Street Bridge, Las Chollas Valley, San Diego. [= SD Loc. 413]
309. Stratum with oysters in building excavation at southeast corner of India and Upas streets, San Diego. [= SD Loc. 415]
310. In small ravine facing west (a little north of south edge of willow patch and a farm road) in west face of terrace, 250 yards north of Mexican boundary and 3/4 mile east of coast. [= CAS Loc. 28885; SD Loc. 416]
311. San Diego, unlocalized.
312. Second ravine north of Loc. 294, fifth ravine north (about 1/4 mile) of the Mexican boundary, at west face of terrace 3/4 mile east of the coast, the ravine debouching near the north end of a willow patch. [= SD Loc. 417; CAS Loc. 28889]
331. San Diego, unlocalized.
1382. *Pecten bellus* beds in cut bank behind a leveling excavation back from 11th Street (eastward) and south of a dirt road across from cobblestone bridge.
1383. *Macoma* beds 20 feet stratigraphically above the *Pecten bellus* beds and just below the terrace gravels in cut bank behind a leveling excavation back from 11th Street (eastward) and south of a dirt road across from the cobblestone bridge, San Diego.
1384. *Pecten healeyi* beds in road cut north of fork in road up ravine, opposite a grove of fir trees and between latitude of Date and Elm streets, San Diego.
1385. *Pecten healeyi* beds in cut bank 1268 to 1410 feet along fork in road emerging just east of Federal Building in Balboa Park Plaza, 10 to 12 feet stratigraphically below *Dosinia* beds at Loc. 1386 (SD).
1386. *Dosinia* beds in cut bank 338 feet along ravine road from Loc. 1385 and just below the southeast corner of the Federal Building in Balboa Park, San Diego.
2359. Soft brown fine-grained sandstone outcropping in a small canyon parallel to and about two-tenths of a mile west of the mouth of Rose Canyon and four tenths mile north of Garnet Avenue (2.6 mile S. 40° E. of triangulation station on Mount Soledad).
2420. Soft Pliocene sands exposed in bluffs along Pacific Beach, about 1/2 mile southeast of False Point, La Jolla quad.

408. Road cut 0.1 mile east of Euclid Avenue on north side of Market Street, San Diego. [= CAS 28880]
409. First prominent cut on west side of road, lower entrance to Mt. Hope Cemetery, between Imperial Avenue and old Cuyamaca railroad (36th Street), San Diego. [= CAS Loc. 28888; UCLA Loc. 303]
412. Between Las Chollas Valley and 32nd and Greeley streets, San Diego. [= UCLA Loc. 412]
413. Large concretionary lenses following bedding of outcrop prominent in bottom of wash, about a block above Market Street Bridge, Las Chollas Valley, San Diego.
415. Oyster layer in building excavation at southeast corner of India and Upas streets, San Diego. [= UCLA Loc. 309]
416. In west face of terrace, 250 yards north of Mexican Boundary, 3/4 mile east of coast. [= CAS Loc. 28885; UCLA 310]
417. Second ravine north of Loc. 331 (SD) and fifth ravine north of Mexican boundary (about 1/4 mile), in west face of terrace about 3/4 mile from the coast. This ravine debouches near the north end of a patch of willows. [= CAS Loc. 28889]
446. Pacific Beach, unlocalized.
1142. Near Fir and Boundary streets, San Diego.
2359. San Diego, unlocalized.
2407. Pacific Beach.
2912. Reynard Way, San Diego.
2915. India Street near Spruce Street, San Diego.
2916. Reynard Way, San Diego.
2930. Reynard Way (formerly known as "Brickyard Canyon"), about 1/4 mile northeast of the old brickyard, in a small gulch southeast of the street.
2931. Reynard Way, San Diego.
2939. Same as Loc. 2930.
2946. Same as Loc. 2930.
2948. Same as Loc. 2930.
2949. Same as Loc. 2930.
2951. Reynard Way, San Diego.
2954. Reynard Way, San Diego.
3203. Kensington Park, San Diego.
3206. Kensington Park, San Diego.
3209. Kensington Park, San Diego.
3592. Reynard Way, San Diego.
4413. Juniper and Boundary Streets, San Diego.
4735. India Street near Spruce Street, San Diego.
5001. Soledad Mountain, San Diego.
5003. Soledad Mountain, San Diego.
5006. Soledad Mountain, San Diego.
5251. Balboa Park, San Diego.
5252. Cabrillo Canyon, Balboa Park.
5679. Las Chollas Valley, San Diego.
6304. Pacific Beach, San Diego.
6307. Pacific Beach, unlocalized.
6386. Pacific Beach, San Diego.
6387. Pacific Beach, San Diego.
6389. Pacific Beach, San Diego.

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103. West side of Reynard Way, between Curlew and Eagle streets, San Diego.
104. West side of Reynard Way, between Curlew and Eagle streets, San Diego.
107. 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego. [= CAS Loc. 33334]
116. Oyster bed at corner of Dove and Maple streets, San Diego.
121. On south side of the junction of Washington Street and University Avenue "Douglas Freeway," continuation of Andrews Place, San Diego.
122. 20 to 30 feet below the end of Loring Street, Pacific Beach.
124. West side of Reynard Way, between Curlew and Eagle streets, San Diego.
127. Shell stratum on Wabash Freeway, Market Street continuation, 1/4 mile south of Euclid Street, Encanto.
180. 2200 block on east side of La Jolla Boulevard at the intersection with Tiras Street, San Diego.
302. Twenty feet of sand and silt above street level across the street from the house at 2840 Columbia Street, San Diego.
302A. In chalky-white marl-like sediment 11 feet thick, 110 feet behind the house at 835 South 32nd Street, San Diego.
305. 2400 feet east and 1350 feet south of northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meriidan (see U.S.G.S. topog. map, San Ysidro quad., ed. 1943).
305A. West side of next gully east of Loc. 305 (LAM) at the same elevation: fossils in float slump and consolidated boulders, silt and sandstone, and silt in place.
305B. A small pocket in gully next to 305A (LAM).
305C. Exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (U.S.G.S. topog. map, San Ysidro quad., rev. 1953).
308. 0.23 mile north of intersection Harbor Boulevard and Tourmaline Street, Pacific Beach.
309. Two canyons east of Kate Sessions School, approximately 0.3 mile west of Balboa Avenue from U. S. 101, turning on to a paved road passing in front of a pink building, San Diego.
318. Just above the gates and cow shed, 200 feet from the road and 30 feet above the valley floor, on Knox Ranch hill.
319. Exactly between United States-Mexico boundary fence and Mr. Ericson's (the manager's) house, 27 feet above the road level on the shoulder of the second hill.
320. 100 feet back of house No. 835, South 32nd Street, San Diego.

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31. Same as Loc. 305A (LAM).
32. South side of Tiajuana River near mouth of Valley; sandstone-siltstone at base of hill south of Monument Road and east of Border Naval Reservation, east side of mouth of a prominent gully west of Goat Canyon, southeast 1/4 Sec. 8, T. 19 S., R. 2 W. (see U.S.G.S. topog. map, San Ysidro quad., ed. 1953). [= LAM Loc. 305A]
47. About six feet stratigraphically above friable sandstone exposed at bottom of gully at Loc. 46 (= 47) which is, south side of Tiajuana River valley; sandstone-siltstone at base of hill south of Monument Road and east of Border Naval Reservation, east side of prominent gully west of Goat Canyon, southeast 1/4 of Sec. 8, T. 19 S., R. 2 W, San Bernardino Base and Meridian (see U.S.G.S. topog. map, San Ysidro quad., ed. 1953). [= LAM Loc. 305C]
222. South side of Mt. Soledad; shell bed at base of cut in bank.
223. South side of Mt. Soledad; shell bed at base of cut in bank and about five feet stratigraphically lower than at Loc. 222 (SDSC).

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A-8333. Same as Loc. 305 (LAM).

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PLATE 27

Fig. 1. *Nucula (Ennucula) balboana* n. sp. Holotype (California Academy of Sciences), from Loc. 12099 (CAS), San Diego well, Balboa Park, San Diego, Calif. Length 13.4 mm.; height 10.7 mm.; convexity (both valves together) 7.2 mm. View of the exterior of the left valve. P. **145**

Fig. 2. *Nucula (Ennucula) balboana* n. sp. Holotype. View of the exterior of the right valve. P. **145**

Fig. 3. *Nucula (Ennucula) balboana* n. sp. Paratype (California Academy of Sciences), from same locality as the holotype shown in fig. 1. Length 11.4 mm. View showing hinge of a left valve. P. **145**

Fig. 4. *Nucula (Ennucula) balboana* n. sp. Holotype. Dorsal view of specimen shown in figs. 1 and 2. P. **145**

Fig. 5. *Nucula (Lamellinucula) exigua* Sowerby. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), second ravine north of Loc. 294 (UCLA), fifth ravine north (about ¼ mile) of the Mexican boundary, at west face of a terrace, ¾ mile east of the coast. Length 4.6 mm.; height 4.8 mm. View of exterior of a right valve. P. **146**

Fig. 6. *Nucula (Lamellinucula) exigua* Sowerby. View of the interior of the valve shown in fig. 5.

Fig. 7. *Acila (Truncacila) castrensis* Hinds. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co., Calif. (see U.S. Geol. Surv. topog. map, San Ysidro quad., ed. 1943). Length 9.5 mm.; height 9.2 mm. View of the exterior of a left valve. P. **147**

Fig. 8. *Acila (Truncacila) castrensis* Hinds. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 10.1 mm.; height 8.2 mm. View of the exterior of a right valve.

Fig. 9. *Acila (Truncacila) castrensis* Hinds. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 9.8 mm.; height 8.2 mm. View of the exterior of a left valve.

Fig. 10. *Acila (Truncacila) castrensis* Hinds. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 9.0 mm.; height 8.0 mm. View of the exterior of a right valve.

Fig. 11. *Nuculana (Saccella) taphria* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 19.3 mm.; height 12.9 mm. View of the exterior of a right valve which is very high in proportion to the length. P. **150**

Fig. 12. *Nuculana (Saccella) taphria* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 16.4 mm.; height 9.6 mm. View of the exterior of a right valve.

Fig. 13. *Nuculana (Saccella) taphria* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 13.7 mm.; height 8.4 mm.

Fig. 14. *Glycymeris (Axinola) grewingki* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 25.1 mm.; height 26.2 mm. View of the exterior of a left valve. P. **159**

Fig. 15. *Glycymeris (Axinola) profunda* Dall. Paratype (No. 696, California Academy of Sciences), from Pacific Beach, San Diego, Calif. Length 23 mm.; height 23.4 mm. View of the exterior of a left valve from the original lot of this species collected by Henry Hemphill.

Fig. 16. *Nuculana (Saccella) taphria* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 18.5 mm.; height 10.3 mm. View of the exterior of a left valve.

Fig. 17. *Nuculana (Saccella) taphria* Dall. View of the interior of the specimen shown in fig. 16.

Fig. 18. *Nuculana (Saccella) taphria* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 21 mm.; height 12.3 mm.

Fig. 19. *Glycymeris (Axinola) grewingki* Dall. View of the interior of the specimen shown in fig. 14.

Fig. 20. *Glycymeris (Axinola) profunda* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 26.4 mm.; height 26.5 mm. View of the exterior of a left valve.

Fig. 21. *Glycymeris (Axinola) profunda* Dall. View of the interior of the specimen shown in fig. 20.

Fig. 22. *Glycymeris (Axinola) grewingki* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 21.2 mm.; height 20 mm. View of the interior of a left valve.

Fig. 23. *Glycymeris (Axinola) profunda* Dall. View of the interior of the specimen shown in fig. 15.

Fig. 24. *Glycymeris (Axinola) grewingki* Dall. View of the exterior of the specimen shown in fig. 22.

Fig. 25. *Glycymeris (Axinola) profunda* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 23.2 mm.; height 25.3 mm. View of the exterior of a left valve.

Fig. 26. *Arca (Arca) sisquocensis* Reinhart. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length (incomplete) 11.2 mm.; height (incomplete) 5.5 mm. View of exterior of the upper portion of a right valve. This specimen virtually disintegrated during the process of photography.

Fig. 27. *Arca (Arca) sisquocensis* Reinhart. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 23.8 mm.; height 16.4 mm. View of the exterior of an incomplete right valve. The specimen, very fragile, partially disintegrated during preparation of a photograph.

Fig. 28. *Glycymeris (Axinola) profunda* Dall. Paratype (No. 696b, California Academy of Sciences), from Pacific Beach, San Diego, Calif. Length 20.8 mm.; height 21.8 mm. View of the exterior of a right valve from the type lot of this species collected by Henry Hemphill.

Fig. 29. *Glycymeris (Axinola) profunda* Dall. View of the interior of the specimen shown in fig. 28.

Fig. 30. *Glycymeris (Axinola) profunda* Dall. Hypotype (San Diego Society of Natural History), from Loc. 150 (SD), upper portion of the section of Pliocene strata at Pacific Beach, San Diego, Calif. View of the hinge of the specimen shown in fig. 37, which is 32.8 mm. long (incomplete) and 35 mm. high.

Fig. 31. *Arca (Arca) sisquocensis* Reinhart. Enlarged view of hinge and ligamental area of the specimen shown in fig. 27.

Fig. 32. *Arca (Arca) sisquocensis* Reinhart. View of the interior of the specimen shown in fig. 26.

Fig. 33. *Arca (Arca) sisquocensis* Reinhart. View of the exterior of the specimen shown in figs. 27 and 31.

Fig. 34. *Glycymeris (Axinola) profunda* Dall. View of the interior of the specimen shown in fig. 25.

Fig. 35. *Barbatia (Fugleria) illota* Sowerby. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 18.3 mm.; height 13.3 mm. View of the exterior of a right valve. P. **157**

Fig. 36. *Barbatia (Fugleria) illota* Sowerby. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 17.5 mm.; height 13 mm. View of the exterior of a left valve.

Fig. 37. *Glycymeris (Axinola) profunda* Dall. View of the exterior of the same specimen shown in fig. 30.

Fig. 38. *Barbatia (Fugleria) illota* Sowerby. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length (anterior end incomplete) 20.1 mm.; height 14.3 mm. View of the interior of a right valve.

Fig. 39. *Barbatia (Fugleria) illota* Sowerby. View of the exterior of the specimen shown in fig. 38.

Fig. 40. *Barbatia (Fugleria) illota* Sowerby. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 15.4 mm.; height 10.5 mm. View of the interior of a left valve. The lack of teeth in the central portion of the hinge is shown clearly in figures 38 and 40.

PLATE 28

Fig. 1. *Anadara trilineata* Conrad. Hypotype (Los Angeles County Museum), from Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co., Calif. (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 67.1 mm.; height 51 mm. View of the interior of a right valve. P. **154**

Fig. 2 *Anadara trilineata* Conrad. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), second ravine north of Loc. 294 (UCLA), fifth ravine north (about ¼ mile) of the Mexican boundary, at west face of a terrace ¾ mile east of the coast. Length 31 mm.; height 21 mm.; convexity (both valves together) 16 mm. View of dorsal area showing the sharply pointed anterior margin when viewed from above. P. **154**

Fig. 3. *Anadara trilineata* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 62 mm.; height 42 mm. View of the interior of a right valve.

Fig. 4. *Anadara trilineata* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 52 mm.; height 40 mm. View of the exterior of a right valve.

Fig. 5. *Anadara trilineata calcarea* Grant and Gale. Hypotype (California Academy of Sciences), from the San Diego Well, Balboa Park, San Diego. Length 74 mm.; height 69 mm.; convexity (both valves together) 46.6 mm. View of dorsal area showing rounded anterior end when viewed from above. P. **156**

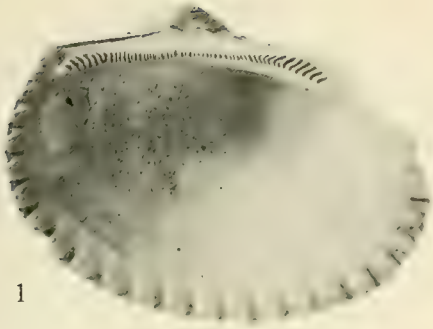
Fig. 6 *Anadara trilineata* Conrad. View of the exterior of the specimen shown in fig. 3.

Fig. 7 *Anadara trilineata calcarea* Grant and Gale. View of the interior of the right valve of the specimen shown in fig. 5.

Fig. 8 *Anadara trilineata calcarea* Grant and Gale. View of the interior of the left valve of the specimen shown in fig. 5.

Fig. 9. *Anadara trilineata calcarea* Grant and Gale. View of the exterior of the valve shown in fig. 8.

Fig. 10. *Anadara trilineata calcarea* Grant and Gale. View of the exterior of the valve shown in fig. 7.



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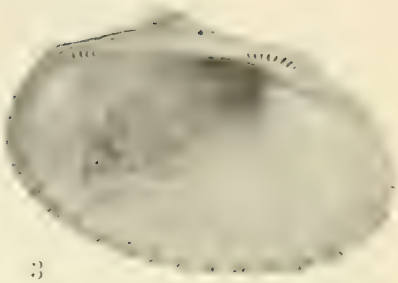

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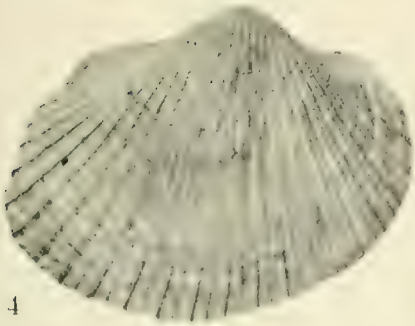

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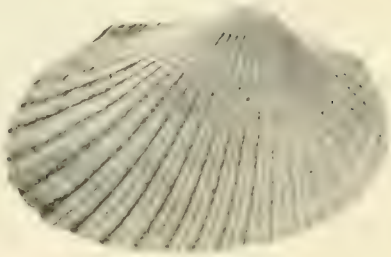

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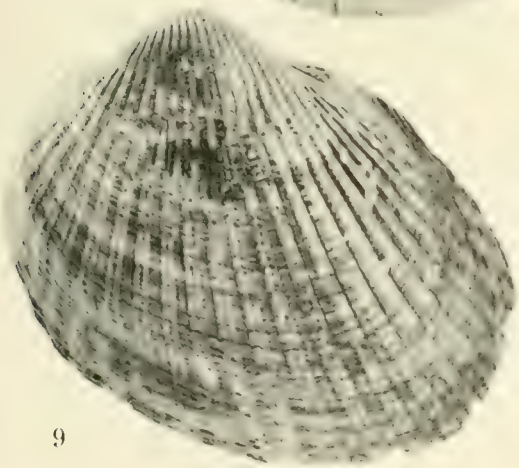

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PLATE 29

Fig. 1. *Pecten (Oppenheimopecten) vogdesi* Arnold. Hypotype (Los Angeles County Museum), from Loc. 320A (LAM), chalky white sediment in exposure 100 feet behind the house at 835 South 32nd Street, San Diego. Length 105 mm.; height 84.4 mm. View of the exterior of a left valve. P. 181

Fig. 2. *Pecten (Flabellipecten) stearnsii* Dall. Paratype (No. 525a, California Academy of Sciences), from Pacific Beach. Length 90.6 mm.; height 78 mm. View of the exterior of a right valve. This specimen is one of the original lot (H. Hemphill, No. 12138) of *Pecten stearnsii*. P. 178

Fig. 3. *Pecten (Oppenheimopecten) vogdesi* Arnold. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 111 mm.; height 106.5 mm. View of the exterior of a right valve. P. 181

Fig. 4. *Pecten (Flabellipecten) stearnsii* Dall. Left valve of the specimen shown in fig. 2.

Fig. 5. *Pecten (Oppenheimopecten) vogdesi* Arnold. Hypotype (Stanford University), from 31st and Logan Avenue, San Diego. Length 94.6 mm.; height (incomplete), 91.4 mm. View of the exterior of a right valve, the umbonal portion lacking. P. 181

Fig. 6. *Pecten (Oppenheimopecten) vogdesi* Arnold. View of the interior of the specimen shown in fig. 1.

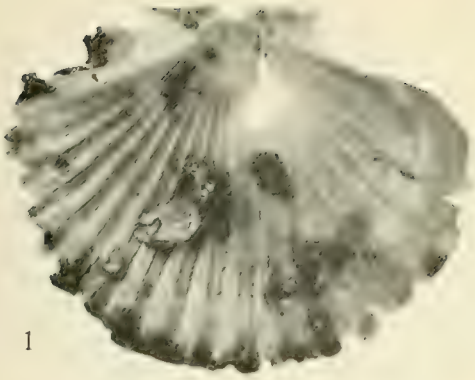

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PLATE 30

Fig. 1. *Pecten (Pecten) bellus* Conrad. Hypotype (California Academy of Sciences), from Pacific Beach. Length 70.4 mm.; height 67.3 mm. View of the exterior of a right valve. This is paratype No. 526b (H. Hemphill No. 12139) from the original lot of *Pecten hemphillii* Dall. P. **174**

Fig. 2. *Pecten (Pecten) bellus* Conrad. Hypotype (California Academy of Sciences), from Pacific Beach. Length 72.5 mm.; height 64 mm. This is paratype No. 526 (H. Hemphill No. 12139) from the original lot of *Pecten hemphillii* Dall.

Fig. 3. *Pecten (Pecten) bellus* Conrad. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 26.6 mm.; height 24.3 mm. View of the exterior of a right valve. P. **174**

Fig. 4. *Pecten (Pecten) bellus* Conrad. Hypotype (California Academy of Sciences), from Pacific Beach. Length 87.3 mm.; height 78.8 mm. This is paratype No. 526a (H. Hemphill No. 12139) from the original lot of *Pecten hemphillii* Dall. Note the broad ribs on this specimen in comparison with those on the specimen shown in fig. 1. P. **174**

Fig. 5. *Chlamys (Chlamys) opuntia* Dall. Hypotype (California Academy of Sciences), from Loc. 1183 (CAS), on Eagle Street just north of Quince Street, just east of Reynard Way, San Diego. Length 34.8 mm.; height 37 mm. View of the exterior of a right valve. P. **192**

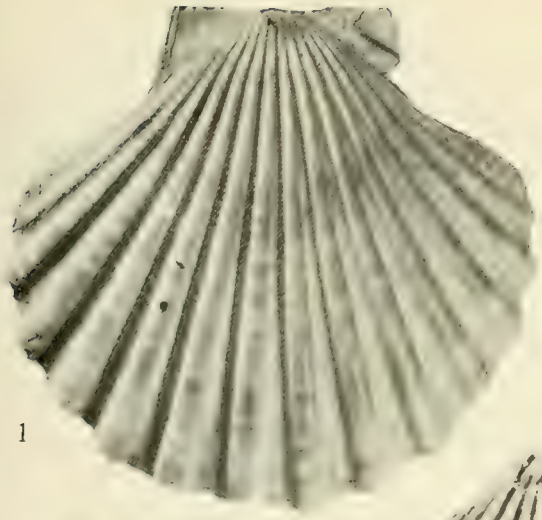
Fig. 6. *Chlamys (Chlamys) opuntia* Dall. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego. Length 38.4 mm.; height 43.5 mm.

Fig. 7 *Chlamys (Argopecten) subdola* Hertlein. Hypotype (California Academy of Sciences), from Loc. 1413 (CAS), lower beds in section of Pliocene strata exposed at Pacific Beach. Length 45.5 mm.; height 45 mm. View of the exterior of a right valve. P. **201**

Fig. 8. *Chlamys (Argopecten) subdola* Hertlein. View of the exterior of the left valve of the specimen shown in fig. 7.

Fig. 9. *Pecten (Pecten) bellus* Conrad, Hypotype (California Academy of Sciences), from Pacific Beach. View of the exterior of the left valve of the specimen shown in fig. 4. This is the exterior of the valve shown on plate 32, fig. 14.

Fig. 10. *Chlamys (Chlamys) jordani* Arnold. Hypotype (California Academy of Sciences), from Loc. 28893 (CAS), corner of India and Upas streets, San Diego. Length 13.8 mm.; height 26.2 mm. View of the exterior of a left valve of a juvenile specimen.



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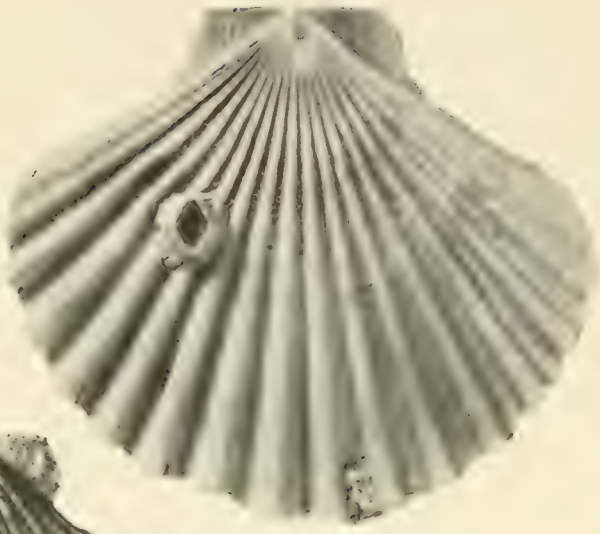

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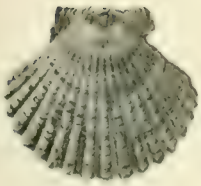

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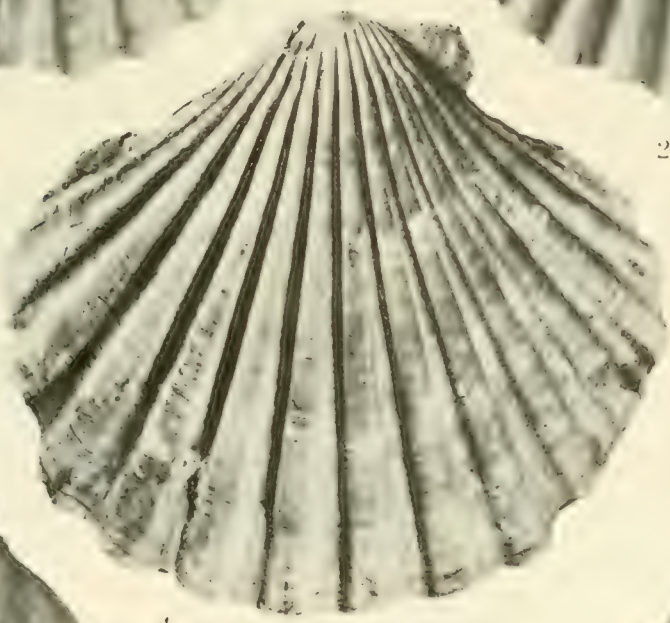

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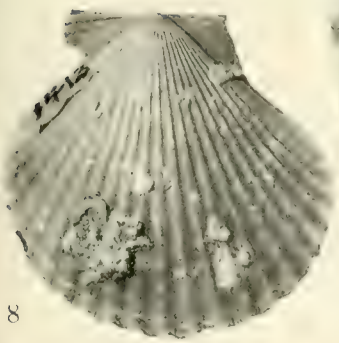

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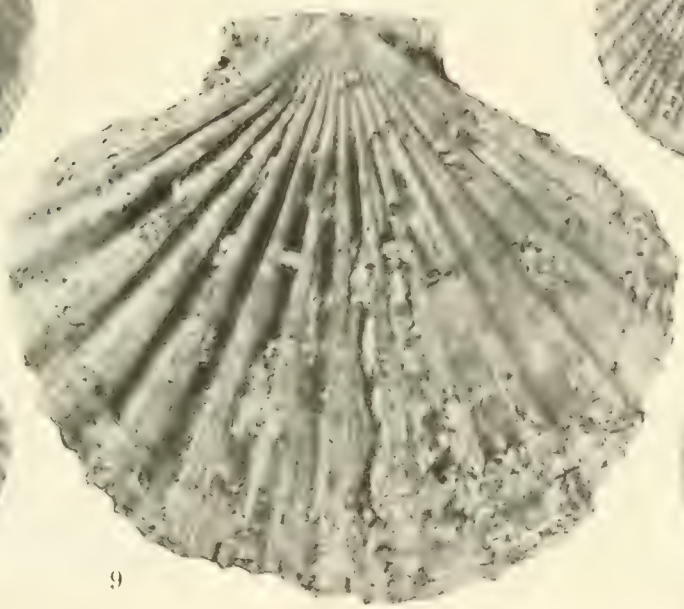

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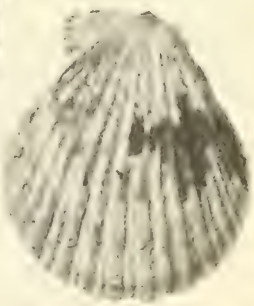

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PLATE 31

Fig. 1 *Pecten (Patinopecten) healeyi* Arnold. Hypotype (San Diego Society of Natural History), from Loc. 365 (SD), second ravine west of mouth of Rose Canyon, south slope of Mount Soledad. Length 139 mm.; height 130 mm. View of the exterior of a left valve. P. **183**

Fig. 2. *Chlamys (Chlamys) hastata ellisi* n. subsp. Holotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 66 mm.; height 68.5 mm. View of the exterior of a right valve. P. **190**

Fig. 3. *Chlamys (Chlamys) hastata ellisi* n. subsp. Enlargement of a portion of the specimen illustrated in fig. 2, showing the honeycomb-like sculpture covering the valve. P. **190**

Fig. 4. *Pecten (Patinopecten) healeyi* Arnold. Paratype from the original lot of *Pecten expansus* Dall (No. 527, California Academy of Sciences), from San Diego. Length 155 mm.; height 146 mm. View of the exterior of a left valve.

Fig. 5 *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 2. Length 31.9 mm.; height 36.8 mm. View of the exterior of a small right valve. P. **206**

Fig. 6 *Pecten (Patinopecten) healeyi* Arnold. View of the exterior of right valve of specimen shown in fig. 4. P. **183**

Fig. 7. *Pecten (Patinopecten) healeyi* Arnold. Hypotype (San Diego Society of Natural History), from Loc. 37 (SD), Pacific Beach. Length 176 mm.; height 165 mm. View of the exterior of a right valve (ends of hinge imperfect), showing radial ribs some of which bear two, some three and occasionally four radial grooves. P. **183**

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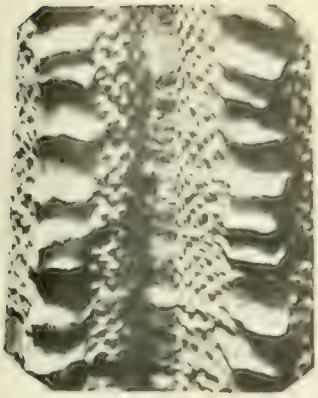

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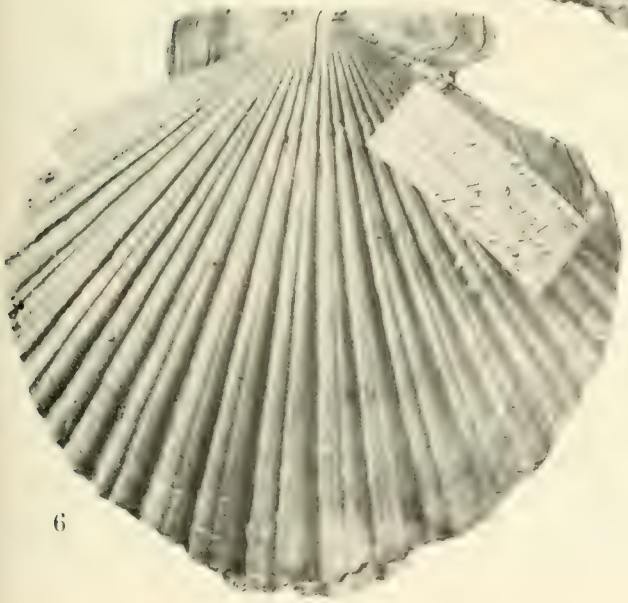

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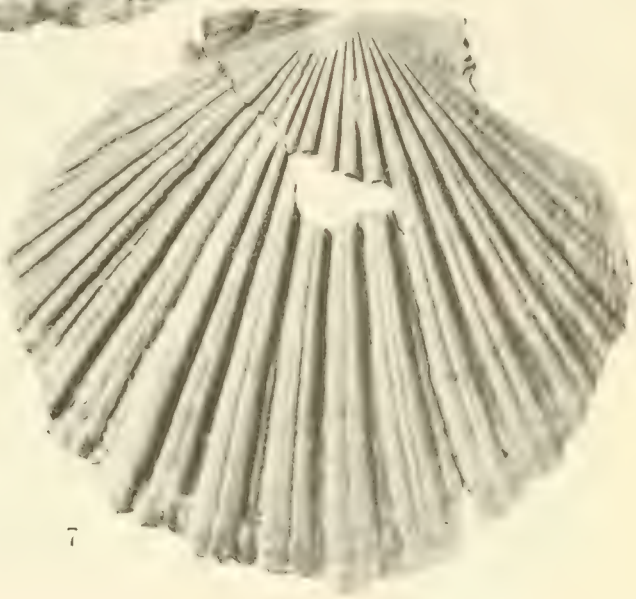

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PLATE 32

Fig. 1. *Chlamys (Leptopecten) bellilamellata* Arnold. Hypotype (California Academy of Sciences), from Loc. 1400 (CAS), in upper portion of section of Pliocene strata at Pacific Beach, San Diego. Length 16 mm.; height 16.5 mm. View of the exterior of a right valve. P. **203**

Fig. 2. *Chlamys (Leptopecten) bellilamellata* Arnold. Hypotype (San Diego Society of Natural History), Loc. 331 (SD), exposure back of house No. 3550 on Dove Street, San Diego. Length 14.7 mm.; height 13.8 mm. View of the exterior of a right valve. P. **203**

Fig. 3. *Chlamys (Chlamys)* cf. *C. (C.) jordani* Arnold. Hypotype (California Academy of Sciences), from Loc. 28893 (CAS), corner of India and Upas streets, San Diego. Length (anterior side imperfect) 28 mm.; height 31 mm. View of the exterior of a right valve with unusually fine ribbing. P. **191**

Fig. 4. *Chlamys (Argopecten) circularis* Sowerby. Hypotype (California Academy of Sciences), from Loc. 1137 (CAS), 31st Street and Logan Avenue, San Diego. Length 28.5 mm.; height 28.6 mm.

Fig. 5. *Chlamys (Chlamys) jordani* Arnold. Hypotype (California Academy of Sciences), from the same locality as the specimen shown in fig. 3. Length 15.6 mm.; height 17.5 mm. P. **191**

Fig. 6. *Chlamys (Chlamys) jordani* Arnold. View of the left valve of the specimen shown in fig. 5. P. **191**

Fig. 7. *Chlamys (Argopecten) ericellus* Hertlein. Holotype (No. 2998, California Academy of Sciences), from Loc. 1132 (CAS), Pacific Beach, San Diego. Length 29.1 mm.; height 28 mm. View of the exterior of a right valve. P. **199**

Fig. 8. *Chlamys (Leptopecten) bellilamellata* Arnold. Hypotype (California Academy of Sciences), from Loc. 105 (CAS), Pacific Beach, San Diego. Length 12.8 mm.; height 12.9 mm. View of the exterior of a left valve. P. **203**

Fig. 9. *Chlamys (Argopecten) callida* Hertlein. Hypotype (California Academy of Sciences), from Loc. 1413 (CAS), from lower portion of the section of Pliocene strata at Pacific Beach. Length 55.4 mm.; height 53.6 mm. View of the exterior of a left valve. P. **198**

Fig. 10. *Chlamys (Argopecten) jordani* Arnold. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego. Length 45.7 mm.; height 47 mm. View of exterior of a right valve, the ears lacking. P. **191**

Fig. 11. *Chlamys (Argopecten) callida* Hertlein. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), Pacific Beach. Length 50 mm.; height 48.4 mm. View of the exterior of a right valve. P. **198**

Fig. 12. *Chlamys (Argopecten) jordani* Arnold. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 10. Length 32.2 mm.; height 34 mm. P. **191**

Fig. 13. *Chlamys (Argopecten) jordani* Arnold. Hypotype (California Academy of Sciences), from Loc. 1132 (CAS), Pacific Beach. Length 23.6 mm.; height 27.3 mm. View of the exterior of a left valve. P. **191**

Fig. 14. *Pecten (Pecten) bellus* Conrad. Paratype of *Pecten hemphillii* Dall, (No. 526a, California Academy of Sciences), from Pacific Beach. Length 87.3 mm.; height 77 mm. View of the interior of a specimen (H. Hemphill No. 12139) from the original lot of *Pecten hemphillii* Dall

Fig. 15. *Chlamys (Argopecten) circularis* Sowerby. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 24.6 mm.; height 25.2 mm. View of the exterior of a left valve. P. **197**

Fig. 16. *Chlamys (Argopecten) circularis* Sowerby. Hypotype (California Academy of Sciences), from the same locality as the specimen shown in fig. 4. Length 24.6 mm.; height 25.2 mm. View of the exterior of a right valve.

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PLATE 33

Fig. 1 *Chlamys (Argopecten) invalida* Hanna. Hypotype (California Academy of Sciences), from Loc. 105 (CAS), Pacific Beach. Length 48 mm.; height 46.4 mm. View of the exterior of a right valve. P. **200**

Fig. 2. *Chlamys (Chlamys) hastata hericius* Gould. Hypotype (California Academy of Sciences), from Loc. 2028 (CAS), Pacific Beach. Length 54 mm.; height 58 mm. View of the exterior of a right valve.

Fig. 3 *Chlamys (Argopecten) invalida* Hanna. Hypotype (California Academy of Sciences), from Loc. 1179 (CAS), lower portion of the Pliocene section exposed at Pacific Beach. Length 35.5 mm.; height 33.3 mm. View of the exterior of a right valve. P. **200**

Fig. 4. *Chlamys (Chlamys) hastata* Sowerby. Hypotype (California Academy of Sciences), from Loc. 1132 (CAS), Pacific Beach. Length 54 mm.; height 61 mm. View of the exterior of a left valve. P. **188**

Fig. 5. *Chlamys (Chlamys) hastata* Sowerby. Hypotype (California Academy of Sciences), from the same locality as the specimen shown in fig. 2. Length 43 mm.; height 48.6 mm. View of the exterior of a right valve. P. **188**

Fig. 6 *Chlamys (Chlamys) hastata* Sowerby. View of the right valve of the specimen shown in fig. 4.

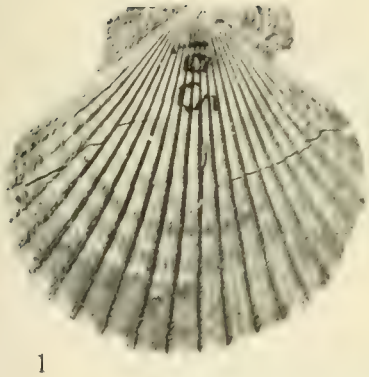
Fig. 7 *Cyclopecten (Cyclopecten) pernomus* Hertlein. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM) at the same elevation. Length 4.2 mm.; height 4.2 mm. View of the exterior of a left valve. P. **213**

Fig. 8 *Chlamys (Argopecten) invalida* Hanna. Hypotype (California Academy of Sciences), from Loc. 1399 (CAS), in bluffs 100 to 200 yards south of the Eocene-Pliocene contact at Pacific Beach. Length 35.4 mm.; height 33.4 mm. View of the exterior of a left valve. P. **200**

Fig. 9 *Pecten (Patinopecten) healeyi* Arnold. Hypotype (California Academy of Sciences), from Loc. 1400 (CAS), upper strata in Pliocene section at Pacific Beach. Length 26.6 mm.; height 27.6 mm. View of the exterior of a juvenile right valve. Traces of vaguely defined radial ribs are present along the ventral margin. The interior lacks any trace of ribs. P. **183**

Fig. 10. *Chlamys (Argopecten) hakei* Hertlein. Hypotype (San Diego Society of Natural History), from Juniper and Boundary streets, San Diego. Length 160 mm.; height 143 mm. View of the exterior of a left valve. P. **199**

Fig. 11. *Cyclopecten (Cyclopecten) pernomus* Hertlein. Hypotype (Los Angeles County Museum), from same locality as the specimen shown in fig. 7. Length 4.2 mm.; height 4.7 mm. View of the interior of a left valve. P. **213**



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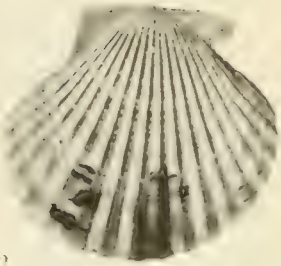

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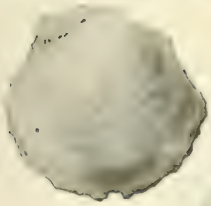

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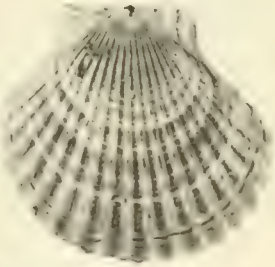

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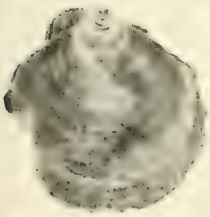

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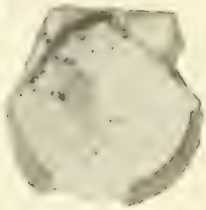

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PLATE 34

Fig. 1. *Chlamys (Lyropecten) cerrosensis* Gabb. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length of hinge line 86 mm. View of the hinge of a left valve showing the well developed crura. P. **209**

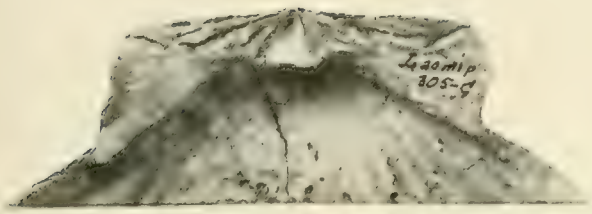
Fig. 2. *Chlamys (Lyropecten) cerrosensis* Gabb. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 147 mm.; height 138 mm. View of the exterior of a right valve. P. **209**

Fig. 3. *Chlamys (Lyropecten) cerrosensis* Gabb. View of the interior of the valve shown in fig. 2.

Fig. 4. *Chlamys (Lyropecten) cerrosensis* Gabb. View of the exterior of the valve shown in fig. 1. Length 156 mm.; height 142 mm.

Fig. 5. *Chlamys (Argopecten) abietis abbotti* n. subsp. Holotype (San Diego Society of Natural History), from exposure at Frontier Housing Project, Loma Portal, San Diego. Length 129.3 mm.; height 117.3 mm. View of the exterior of a right valve. P. **196**

Fig. 6. *Chlamys (Chlamys) hastata ellisi* n. subsp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 2. Length 17.9 mm.; height 20.8 mm. View of the exterior of a left valve. P. **190**



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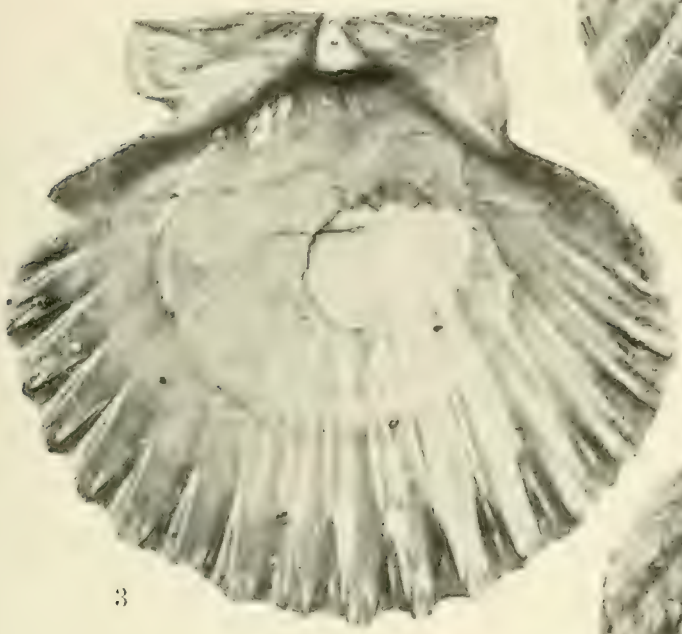

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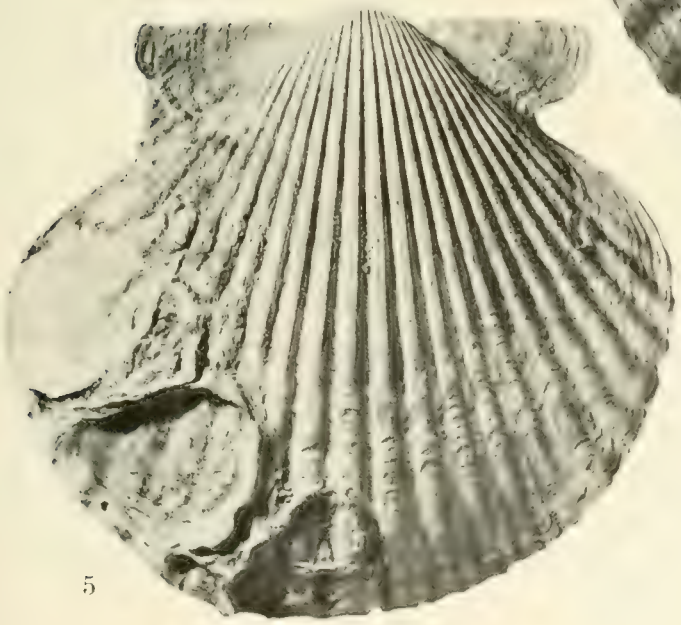

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PLATE 35

Fig. 1 *Chlamys (Leptopecten) latiaurata* Conrad. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), second ravine north of Loc. 294 (UCLA), and fifth ravine north (about ¼ mile) of the Mexican boundary at west face of a terrace ¾ mile east of the coast. Length 17 mm.; height 17.3 mm. View of the exterior of a right valve. P. **203**

Fig. 2. *Chlamys (Argopecten) subdola* Hertlein. Hypotype (California Academy of Sciences), from Loc. 1401 (CAS), first canyon west of Rose Canyon, south slope of Mount Soledad. Length 64 mm.; height 61.3 mm. View of the exterior of a right valve. P. **201**

Fig. 3. *Chlamys (Leptopecten) latiaurata* Conrad. View of the interior of the specimen shown in fig. 1.

Fig. 4. *Pecten (Lituyapecten) dilleri* Dall. Hypotype (University of California at Los Angeles), from Loc. 309 (UCLA), corner of India and Upas streets, San Diego. Length 88.6 mm.; height 88 mm. View of the exterior of a right valve. P. **186**

Fig. 5 *Chlamys (Argopecten) subdola* Hertlein. View of the left valve of the specimen shown in fig. 2

Fig. 6 *Chlamys (Chlamys) rubida* Hinds. Hypotype (San Diego Society of Natural History), from Loc. 4736 (SD), India Street near Spruce Street, San Diego. Length 59.8 mm.; height 64 mm. View of the exterior of a left valve.

Fig. 7 *Pecten (Lituyapecten) dilleri* Dall. View of the exterior of the left valve of the specimen shown in fig. 4.

Fig. 8 *Chlamys (Chlamys) rubida* Hinds. Hypotype (Los Angeles County Museum), from Loc. 107 (CAS), clay quarry at end of Arroyo Drive, San Diego. Length 57.9 mm.; height 52.6 mm. View of the exterior of a right valve, the anterior ear imperfect. P. **193**

Fig. 9. *Chlamys (Argopecten) subdola* Hertlein. Hypotype (San Diego Society of Natural History), from Loc. 408 (SD), road cut 0.1 mile east of Euclid Avenue on north side of Market Street, San Diego. Length 40.5 mm.; height 41.8 mm. View of the exterior of a right valve. P. **201**

Fig. 10. *Pecten (Flabellipecten) stearnsii* Dall. View of the interior of the specimen shown on plate 29, fig. 2. P. **178**

Fig. 11. *Lima (Limaria) orcutti* n. sp. Paratype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 38.6 mm.; height 43.2 mm. View of the interior of a right valve. P. **215**

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PLATE 36

Fig. 1 *Chlamys (Argopecten) abietis abbotti* n. subsp. Holotype (San Diego Society of Natural History), from cut in exposure of strata at Frontier Housing Project, Loma Portal, San Diego. Length 129.0 mm.; height 118.0 mm. View of the exterior of a left valve. Fine fringing lamellae on the sides of the ribs on the upper half of the shell are shown in this illustration. P. **196**

Fig. 2. *Lima (Limaria) orcutti* n. sp. Holotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 35.5 mm.; height 43 mm. View of the exterior of a right valve. P. **215**

Fig. 3 *Lima (Limaria) orcutti* n. sp. View of the interior of the specimen shown in fig. 2.

Fig. 4 *Lima (Limaria) orcutti* n. sp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in figs. 2 and 3. Length 27.6 mm.; height 34.5 mm. View of the exterior of a left valve.

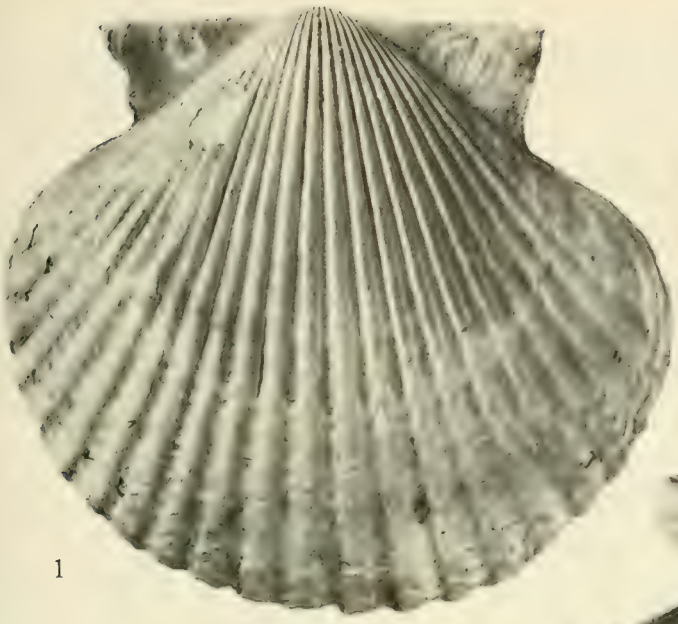
Fig. 5. *Lima (Limaria) orcutti* n. sp. View of the interior of the specimen shown in fig. 4.

Fig. 6. *Chlamys (Argopecten) abietis abbotti* n. subsp. View of the interior of the right valve of the specimen shown in fig. 1.

Fig. 7 *Chlamys (Lyropecten) cerrosensis* Gabb. Hypotype (California Academy of Sciences), from Loc. 12142 (H. Hemphill Coll.), from San Diego. Length 137 mm.; height (incomplete) 111 mm. View of the exterior of a right valve showing the strong radial striations over the entire valve. P. **209**

Fig. 8 *Pecten (Patinopecten) healeyi* Arnold. Hypotype (California Academy of Sciences) from Loc. 105 (CAS), Pacific Beach, San Diego. Length 28.4 mm.; height 29.5 mm. View of the exterior of a small left valve. P. **183**

Fig. 9. *Pecten (Patinopecten) healeyi* Arnold. Hypotype (California Academy of Sciences), from Loc. 105 (CAS), Pacific Beach, San Diego. Length 37 mm.; height 38.8 mm. View of the exterior of a small right valve showing the smooth early umbonal area. See also plate 33, fig. 9. P. **183**



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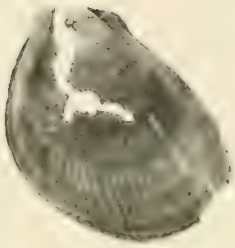

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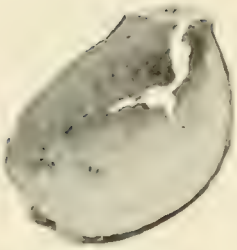

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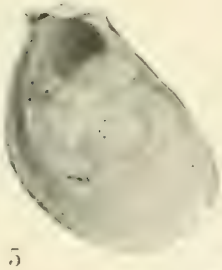

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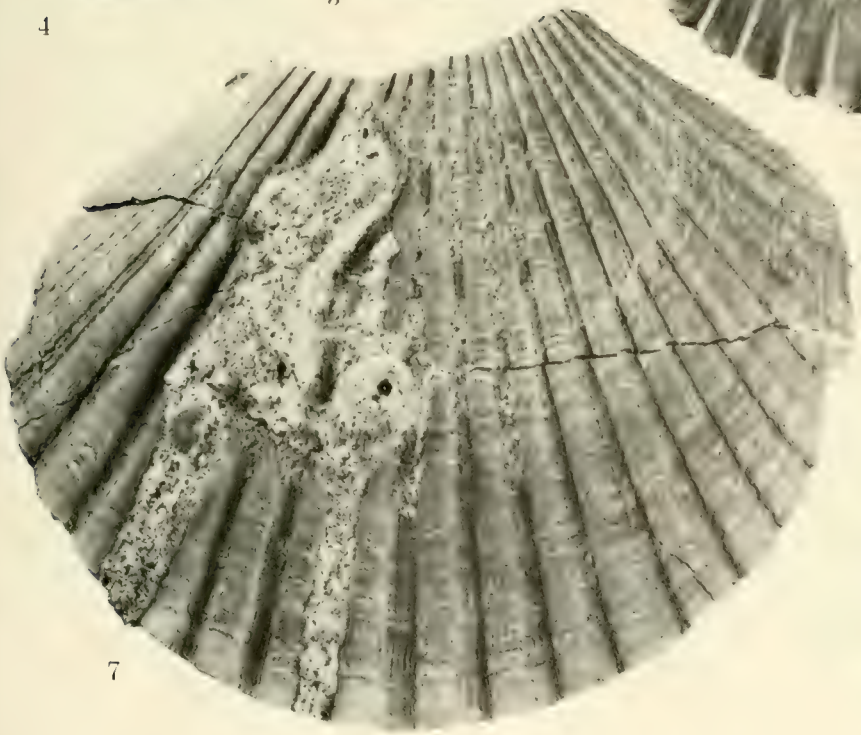

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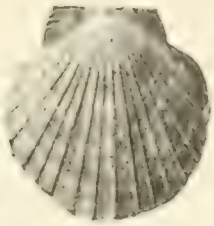

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PLATE 37

Fig. 1. *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co., Calif. (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 43.6 mm.; height 48.8 mm. View of the exterior of a left valve. P. 206

Fig. 2. *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length (incomplete) 46.0 mm.; height (incomplete) 86.5 mm. View of a portion of a right valve on which the radial folds are only faintly developed and concentric undulation is almost lacking. P. 206

Fig. 3 *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 43.6 mm.; height 48.5 mm. View of the exterior of a right valve. P. 206

Fig. 4 *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 56.6 mm.; height 62.5 mm. View of the exterior of a right valve. P. 206

Fig. 5. *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (San Diego Society of Natural History), from Loc. 4735 (SD), India Street near Spruce Street, San Diego. Length 64.8 mm.; height 71.6 mm. View of the interior of a right valve showing cardinal crura. The end of the anterior ear is imperfect as a result of accidental damage since the exterior was drawn as shown in text fig. 10. P. 206

Fig. 6 *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length (incomplete) 54 mm.; height 83.6 mm. View of a portion of a large right valve. P. 206

Fig. 7. *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 72.0 mm.; height 81.2 mm. View of the exterior of a left valve. P. 206

Fig. 8 *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 11.5 mm.; height 12.8 mm. View of the exterior of a juvenile right valve.

Fig. 9 *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 8.3 mm.; height 9 mm. View of the exterior of a juvenile left valve.

Fig. 10. *Chlamys (Swiftopecten) parmeleei* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 66 mm.; height 75.2 mm. View of the exterior of a left valve.

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PLATE 38

Fig. 1. *Ostrea (Agerostrea) megodon* Hanley. Hypotype (University of California at Los Angeles), from Loc. 2420 (UCLA), soft yellow Pliocene sands exposed in bluffs along Pacific Beach, about ½ mile southeast of False Point, La Jolla quadrangle, San Diego. Height (maximum) 37 mm.; width (maximum) 26.0 mm. View of the exterior of the lower valve. P. 221

Fig. 2. *Ostrea angelica* Rochebrune. Hypotype (University of California at Los Angeles), from Loc. 303 (UCLA), first prominent cut on west side of the road, at lower entrance to Mt. Hope Cemetery between Imperial Avenue and old Cuyamaca Railroad (36th Street), San Diego. Height (beak to ventral margin) 113.3 mm.; width 81 mm. View of the exterior of a lower valve. P. 216

Fig. 3. *Ostrea angelica* Rochebrune. View of the interior of the specimen shown in fig. 2.

Fig. 4. *Ostrea erici* Hertlein. Hypotype (Los Angeles County Museum), from Loc. 124 (LAM), shell and echini stratum 15 feet below the school floor level of "Snyder's Continuation School." Height (beak to ventral margin) 69.6 mm.; width 50.4 mm. View of the interior of an upper valve. P. 217

Fig. 5. *Ostrea Agerostrea) megodon* Hanley. View of the exterior of the upper valve of the specimen shown in fig. 1.

Fig. 6. *Ostrea erici* Hertlein. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego. Height (beak to ventral margin) 65.8 mm.; width 58.6 mm. View of the exterior of an upper valve and marginal portion of the lower valve. P. 217

Fig. 7. *Ostrea (Agerostrea) megodon* Hanley. View of the interior of the lower valve shown in fig. 1.

Fig. 8. *Ostrea erici* Hertlein. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 6. Height (beak to ventral margin) 90 mm.; width 86.5 mm. View of the exterior of a lower valve.

Fig. 9. *Ostrea erici* Hertlein. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 6. Height 97 mm.; width (incomplete) 69.5 mm. View of the interior of a lower valve.

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PLATE 39

Fig. 1. *Ostrea vespertina* Conrad. Hypotype (California Academy of Sciences), from Loc. 36555 (CAS), south side of Tijuana River near the mouth of the valley, at base of hill south of monument road and east of Border Naval Reservation [=Loc. 305A (LAM)]. Height 48 mm.; width 37.5 mm. View of the lower of the lower valve showing denticles along the dorsal margin. P. 218

Fig. 2. *Ostrea vespertina* Conrad. Hypotype (California Academy of Sciences), from the same locality as specimen shown in fig. 1. Height 46.4 mm.; width 37.4 mm. View of the interior of an upper valve, showing muscle impression and denticles along dorsal margin. P. 218

Fig. 3. *Ostrea vespertina* Conrad. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), second ravine north of Loc. 294 (UCLA) and fifth ravine north (about ¼ mile) of the Mexican boundary, at west face of terrace ¾ mile east of the coast. Height 40.6 mm.; width 33.1 mm. View of the interior of an upper valve, showing muscle impression and denticles along dorsal margin. P. 218

Fig. 4 *Ostrea veatchii* Gabb. Holotype (No. 4502, Academy of Natural Sciences of Philadelphia). Cedros Island, Lower California; Pliocene. Height 75 mm.; width 69 mm. View showing interior of a left valve, completely lacking denticles along the dorsal margin.

Fig. 5. *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum) from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8. T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co. (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Height 53.5 mm.; width 46 mm. View of exterior of lower valve showing fluting and area of attachment. P. 218

Fig. 6. *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum), view of upper valve of the specimen shown in fig. 5. P. 218

Fig. 7 *Ostrea vespertina* Conrad. Hypotype (California Academy of Sciences). View of the exterior of the specimen shown in fig. 2. P. 218

Fig. 8 *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 5. Height 69 mm.; width 74 mm. View of a rather round lower (left) valve.

Fig. 9. *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum). Upper valve of the specimen shown in fig. 8. P. 218

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PLATE 39

Fig. 1. *Ostrea vespertina* Conrad. Hypotype (California Academy of Sciences), from Loc. 36555 (CAS), south side of Tijuana River near the mouth of the valley, at base of hill south of monument road and east of Border Naval Reservation [= Loc. 305A (LAM)]. Height 48 mm.; width 37.5 mm. View of the lower of the lower valve showing denticles along the dorsal margin. P. 218

Fig. 2. *Ostrea vespertina* Conrad. Hypotype (California Academy of Sciences), from the same locality as specimen shown in fig. 1. Height 46.4 mm.; width 37.4 mm. View of the interior of an upper valve, showing muscle impression and denticles along dorsal margin. P. 218

Fig. 3. *Ostrea vespertina* Conrad. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), second ravine north of Loc. 294 (UCLA) and fifth ravine north (about ¼ mile) of the Mexican boundary, at west face of terrace ¾ mile east of the coast. Height 40.6 mm.; width 33.1 mm. View of the interior of an upper valve, showing muscle impression and denticles along dorsal margin. P. 218

Fig. 4 *Ostrea veatchii* Gabb. Holotype (No. 4502, Academy of Natural Sciences of Philadelphia). Cedros Island, Lower California; Pliocene. Height 75 mm.; width 69 mm. View showing interior of a left valve, completely lacking denticles along the dorsal margin.

Fig. 5. *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum) from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8. T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co. (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Height 53.5 mm.; width 46 mm. View of exterior of lower valve showing fluting and area of attachment. P. 218

Fig. 6. *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum), view of upper valve of the specimen shown in fig. 5. P. 218

Fig. 7 *Ostrea vespertina* Conrad. Hypotype (California Academy of Sciences). View of the exterior of the specimen shown in fig. 2. P. 218

Fig. 8 *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 5. Height 69 mm.; width 74 mm. View of a rather round lower (left) valve.

Fig. 9 *Ostrea vespertina* Conrad. Hypotype (Los Angeles County Museum). Upper valve of the specimen shown in fig. 8. P. 218

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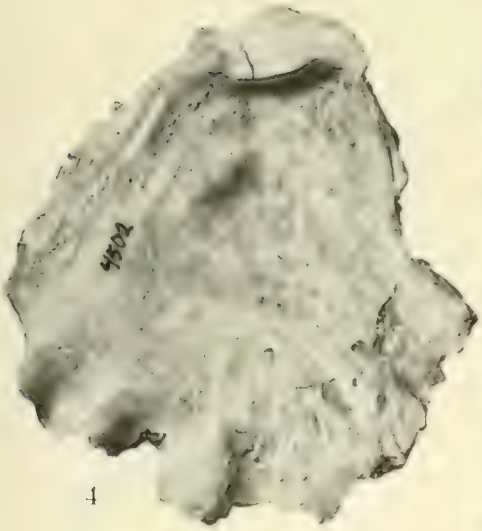

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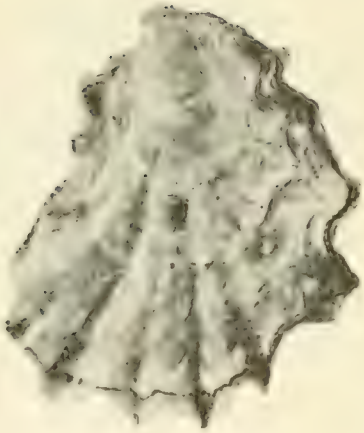

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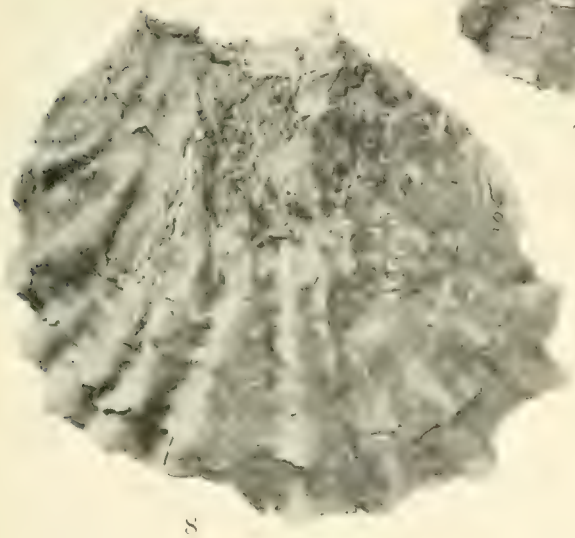

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PLATE 40

Fig. 1. *Ostrea veatchii* Gabb. Hypotype (San Diego Society of Natural History), from Loc. 6307 (SD), Pacific Beach, San Diego. Length 146.5 mm.; height (including spines) 116.5 mm. View of exterior of a large valve to which other smaller valves are attached. P. 219

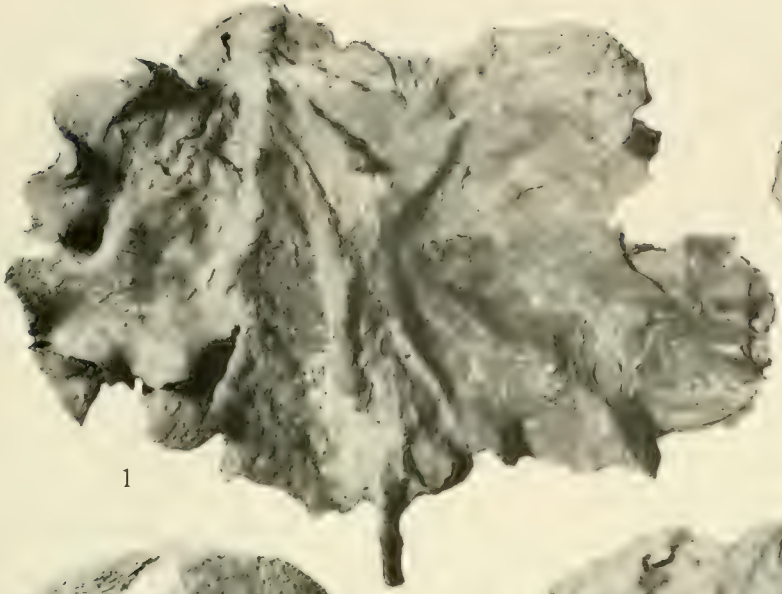
Fig. 2. *Anomia peruviana* d'Orbigny. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 16 mm.; height 12.5 mm. View of exterior of a small upper valve, the margin imperfect. P. 223

Fig. 3. *Pododesmus macrochisma* Deshayes. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 79 mm.; height 73 mm. View of the exterior of an upper valve. P. 225

Fig. 4. *Ostrea veatchii* Gabb. Hypotype (San Diego Society of Natural History). View of the interior of the specimen shown in fig. 1. Margin completely lacks denticles. P. 219

Fig. 5. *Ostrea veatchii* Gabb. Hypotype (Los Angeles County Museum), from Cedros Island, Lower California, Mexico; Pliocene. Length 100 mm.; height 106.5 mm. View of the exterior of the lower valve showing deep plications and spines. P. 219

Fig. 6. *Ostrea veatchii* Gabb. Hypotype (Los Angeles County Museum). View of the interior of the specimen shown in fig. 5. The margins are devoid of denticles. See also fig. 4 on plate 39. P. 219



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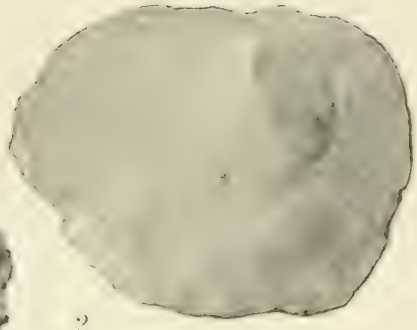

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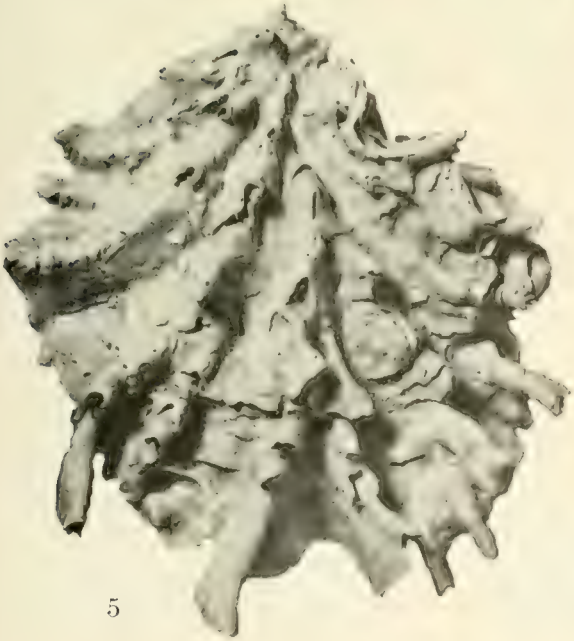

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PLATE 41

Fig. 1. *Gregariella chenui* Recluz. Hypotype (Los Angeles County Museum) from Loc. 305 (CAS), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 4.6 mm.; height 2.5 mm. View of the exterior of a right valve. P. 168

Fig. 2. *Modiolus sacculifer* Berry. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length (incomplete) 22 mm.; height 10 mm. View showing the projecting anterior end of a left valve. P. 167

Fig. 3. *Modiolus sacculifer* Berry. View of the exterior of the specimen shown in fig. 2.

Fig. 4. *Modiolus sacculifer* Berry. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length (anterior end incomplete), 49 mm.; height 34 mm. Ventral margin imperfect. P. 167

Fig. 5. *Gregariella chenui* Recluz. View of the interior of the specimen shown in fig. 1.

Fig. 6. *Periploma stenopa* Woodring. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM) at the same elevation. Length 56.5 mm.; height 38.4 mm. View of exterior of a left valve. P. 337

Fig. 7. *Periploma stenopa* Woodring. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 6. Length (posterior end incomplete) 57 mm.; height 40.5 mm. Dorsal view. P. 337

Fig. 8. *Anomia peruviana* d'Orbigny. Hypotype (California Academy of Sciences), from Loc. 1400 (CAS), strata in upper part of Pliocene section at Pacific Beach. Length 35.5 mm.; height (incomplete) 35.8 mm. View of the exterior of an upper valve, the dorsal area incomplete. P. 223

Fig. 9. *Pododesmus macrochisma* Deshayes. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 62 mm.; height 58.9 mm. View of the exterior of an upper valve. P. 225

Fig. 10. *Mytilus (Crenomytilus) coalingensis sternbergi* new subspecies. Paratype (Los Angeles County Museum), from Loc. 302 (LAM) exposure across the street from the house at 2840 Columbia Street, San Diego. Length (incomplete) 48.8 mm.; height (incomplete) 34 mm. View of the interior of the umbonal portion of a left valve. P. 163

Fig. 11. *Crenella inflata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3 mm.; height 2.3 mm. View of the exterior of a right valve. P. 171

Fig. 12. *Pododesmus macrochisma* Deshayes. Hypotype (University of California at Los Angeles), from Loc. 2420 (UCLA), soft sands of Pliocene age at Pacific Beach. Length 52.5 mm.; height 46.8 mm. View of the interior of an upper valve. P. 225

Fig. 13. *Pododesmus macrochisma* Deshayes. View of the exterior of the specimen shown in fig. 12.

Fig. 14. *Mytilus (Crenomytilus) coalingensis sternbergi* n. subsp. Holotype (Los Angeles County Museum), from Loc. 107 (LAM), 100-foot bluff with fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego. Length 238 mm.; height 134 mm. View of the exterior of the left valve. P. 163

Fig. 15. *Macoma (Rexithaerus) indentata tenuirostris* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 29.3 mm.; height 16 mm. View of the exterior of a right valve. P. 297

Fig. 16. *Hinnites giganteus* Gray. Hypotype (Los Angeles County Museum), from strata of Pliocene age at Pacific Beach. Length 73.0 mm.; height 76.4 mm. View of the exterior of an upper valve. P. 211

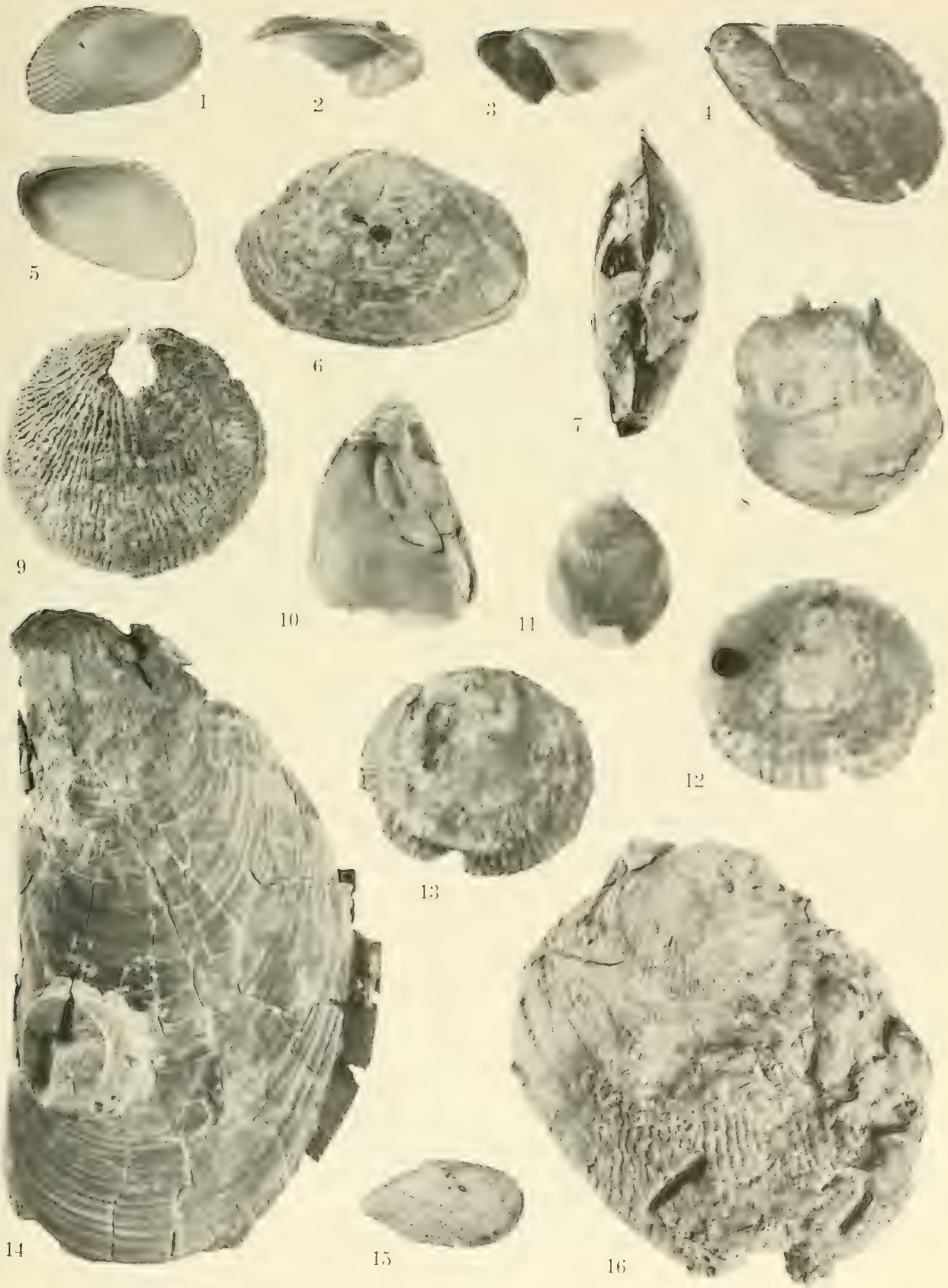
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PLATE 42

Fig. 1. *Gregariella chenui* Recluz. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill 100 feet west and 440 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 4.6 mm.; height 2.5 mm. Enlarged view of the exterior of a right valve, also illustrated on plate 41, fig. 1.

Fig. 2. *Pandora (Heteroclidus) punctata* Conrad. Hypotype (University of California at Los Angeles), from Loc. 1386 (UCLA), *Dosinia* beds in cut bank along a ravine road just below the southeast corner of the Federal Building in Balboa Park, San Diego. Length (incomplete) 28 mm.; height (incomplete) 12 mm. View of the hinge of a left valve. P. 336

Fig. 3. *Pandora (Heteroclidus) punctata* Conrad. Hypotype (University of California at Los Angeles), from the same locality as the specimen shown in fig. 2. Length (incomplete) 34.5 mm.; height (incomplete) 13.8 mm. View of the hinge of a right valve. P. 336

Fig. 4. *Aeidimytilus adamsianus* Dunker. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 18.9 mm.; height 7.2 mm. View of the exterior of a right valve. P. 164

Fig. 5. *Aeidimytilus adamsianus* Dunker. View of the interior of a specimen shown in fig. 4.

Fig. 6. *Septifer bifurcatus* Conrad. Hypotype (San Diego Society of Natural History), from Loc. 47 (SDSC), south side of Tijuana River near mouth of valley; east side of mouth of prominent gully west of Goat Canyon, southeast ¼, Sec. 8, T. 19 S., R. 2 W., (See U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1953). Length 18.3 mm.; height 10.3 mm. View of the interior of a left valve. P. 165

Fig. 7. *Modiolus rectus* Conrad. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM) at the same elevation. Length (anterior end incomplete) 55 mm.; height 41.8 mm. View of the exterior of a right valve. P. 166

Fig. 8. *Gregariella chenui* Recluz. View of the interior of the specimen shown in fig. 1.

Fig. 9. *Pandora (Heteroclidus) punctata* Conrad. Hypotype (San Diego Society of Natural History), from Loc. 21 (SD), embankment at the beach at west end of Diamond Street, Pacific Beach. Length 41.5 mm.; height 25.8 mm. View of the exterior of a right valve. P. 336

Fig. 10. *Pandora (Heteroclidus) punctata* Conrad. View of the exterior of the left valve of the specimen shown in fig. 9.

Fig. 11. *Thracia kanakoffi* n. sp. Holotype (Los Angeles County Museum), from Loc. 291 (LAM), silt beds exposed in a gully in the center of the south ½ Sec. 27, T. 4 N., R. 15 W., San Bernardino Base and Meridian; ½ mile south of the Humphrey railroad station, Los Angeles Co., Calif.; Pico formation, middle Pliocene. Length 81.0 mm.; height 54.2 mm. View of the exterior of the right valve. P. 338

Fig. 12. *Septifer bifurcatus* Conrad. View of the exterior of the specimen shown in fig. 6.

Fig. 13. *Thracia kanakoffi* n. sp. Paratype (San Diego Society of Natural History), from Loc. 34 (SD), northeast corner of India and Thorn streets, San Diego. Length 48 mm.; height 34.4 mm. View of the exterior of a left valve.

Fig. 14. *Thracia kanakoffi* n. sp. View of the left valve of the specimen shown in fig. 11.

Fig. 15. *Thracia kanakoffi*. Dorsal view of the specimen shown in figs. 11 and 12. A low ridge near the right posterior dorsal margin, a characteristic feature of this species, is visible in this view.

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Fig. 1 *Milneria minima* Dall. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co., Calif. (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 5.3 mm.; height 3.2 mm. View of the exterior of a right valve. P. 234

Fig. 2. *Milneria minima* Dall. View of the interior of the specimen shown in fig. 1.

Fig. 3 *Cyclocardia ventricosa* Gould. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 16.2 mm.; height 14.9 mm. View of the interior of a left valve. P. 231

Fig. 4 *Cyclocardia occidentalis* Conrad. Hypotype (University of California at Los Angeles), from Loc. 2359 (UCLA), in small canyon parallel to and about 0.2 mile west of the mouth of Rose Canyon and 0.4 mile north of Garnet Avenue, La Jolla quad., San Diego. Length 11.6 mm.; height 12 mm. View of the interior of a right valve. P. 230

Fig. 5. *Cyclocardia occidentalis* Conrad. Hypotype (University of California at Los Angeles), from North Snyder School, Cabrillo Freeway, San Diego. Length 14 mm.; height 14 mm. View of the interior of a left valve. P. 230

Fig. 6. *Cyclocardia occidentalis* Conrad. View of the exterior of the valve shown in fig. 5.

Fig. 7 *Diplodonta (Felaniella) cornea* Reeve. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length (incomplete) 8.5 mm. View showing hinge of a right valve. P. 253

Fig. 8 *Cyclocardia ventricosa* Gould. View of the exterior of the specimen shown in fig. 3.

Fig. 9. *Cyclocardia occidentalis* Conrad. View of the exterior of the specimen shown in fig. 4.

Fig. 10. *Cyclocardia occidentalis* Conrad. Hypotype (University of California at Los Angeles), from the same locality as the specimen shown in fig. 4. Length 11 mm.; height 11 mm. View of the exterior of a small right valve. P. 230

Fig. 11. *Cyclocardia occidentalis* Conrad. Hypotype (University of California at Los Angeles), from the same locality as the specimen shown in fig. 4. Length 9.5 mm.; height 9.8 mm.

Fig. 12. *Chama pellucida* Broderip. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 26.6 mm.; height (incomplete) 27 mm. View of the exterior of an upper valve. P. 227

Fig. 13. *Diplodonta (Felaniella) cornea* Reeve. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 10.5 mm.; height 10.5 mm. View of the interior of a left valve. P. 253

Fig. 14. *Milneria minima* Dall. View of enlarged portion of the specimen shown in fig. 2, showing hinge.

Fig. 15. *Chama pellucida* Broderip. View of the interior of the specimen shown in fig. 12.

Fig. 16. *Glans subquadrata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 5.5 mm.; height 3.7 mm.

Fig. 17. *Thyasira gouldii* Philippi. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.1 mm.; height 4.3 mm. P. 255

Fig. 18. *Glans subquadrata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.5 mm.; height 3.3 mm. View of the exterior of a left valve. P. 232

Fig. 19. *Glans subquadrata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.6 mm.; height 2.9 mm. View of the interior of a right valve. P. 232

Fig. 20. *Diplodonta (Felaniella) cornea* Reeve. View of the exterior of the specimen shown in fig. 13.

Fig. 21. *Thyasira gouldii* Philippi. Hypotype (University of California at Los Angeles), from Loc. 294 (UCLA), 200 feet north of the Mexican boundary and ¾ mile from the coast. Pliocene exposure in east-west ravine, tributory to a larger south-north ravine at right angle in first terrace above the Tiajuana River plain. Length 8.1 mm.; height 8.1 mm. View of the exterior of a right valve. P. 255

Fig. 22. *Glans subquadrata* Carpenter. View of the interior of the specimen shown in fig. 16.

Fig. 23. *Verticordia (Trigonulina) ornata* d'Orbigny. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 5.3 mm.; height 4.3 mm. View of the exterior of a left valve. P. 344

Fig. 24. *Crassinella branneri* Arnold. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 8.7 mm.; height (incomplete) 8.0 mm. View of the interior of a left valve, the apical portion lacking. P. 228

Fig. 25. *Crassinella branneri* Arnold. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 7.0 mm.; height 6.1 mm. View of the interior of a right valve. P. 228

Fig. 26. *Verticordia (Trigonulina) ornata* d'Orbigny. View of the exterior of the right valve of the specimen shown in fig. 23.

Fig. 27. *Verticordia (Trigonulina) ornata* d'Orbigny. View of the interior of the specimen shown in fig. 26.

Fig. 28. *Crassinella branneri* Arnold. View of the exterior of the specimen shown in fig. 24.

Fig. 29. *Crassinella branneri* Arnold. View of the exterior of the specimen shown in fig. 25.

Fig. 30. *Glans subquadrata* Carpenter. View of the exterior of the specimen shown in fig. 19.

Fig. 31. *Verticordia (Trigonulina) ornata* d'Orbigny. View of the interior of the specimen shown in fig. 23.

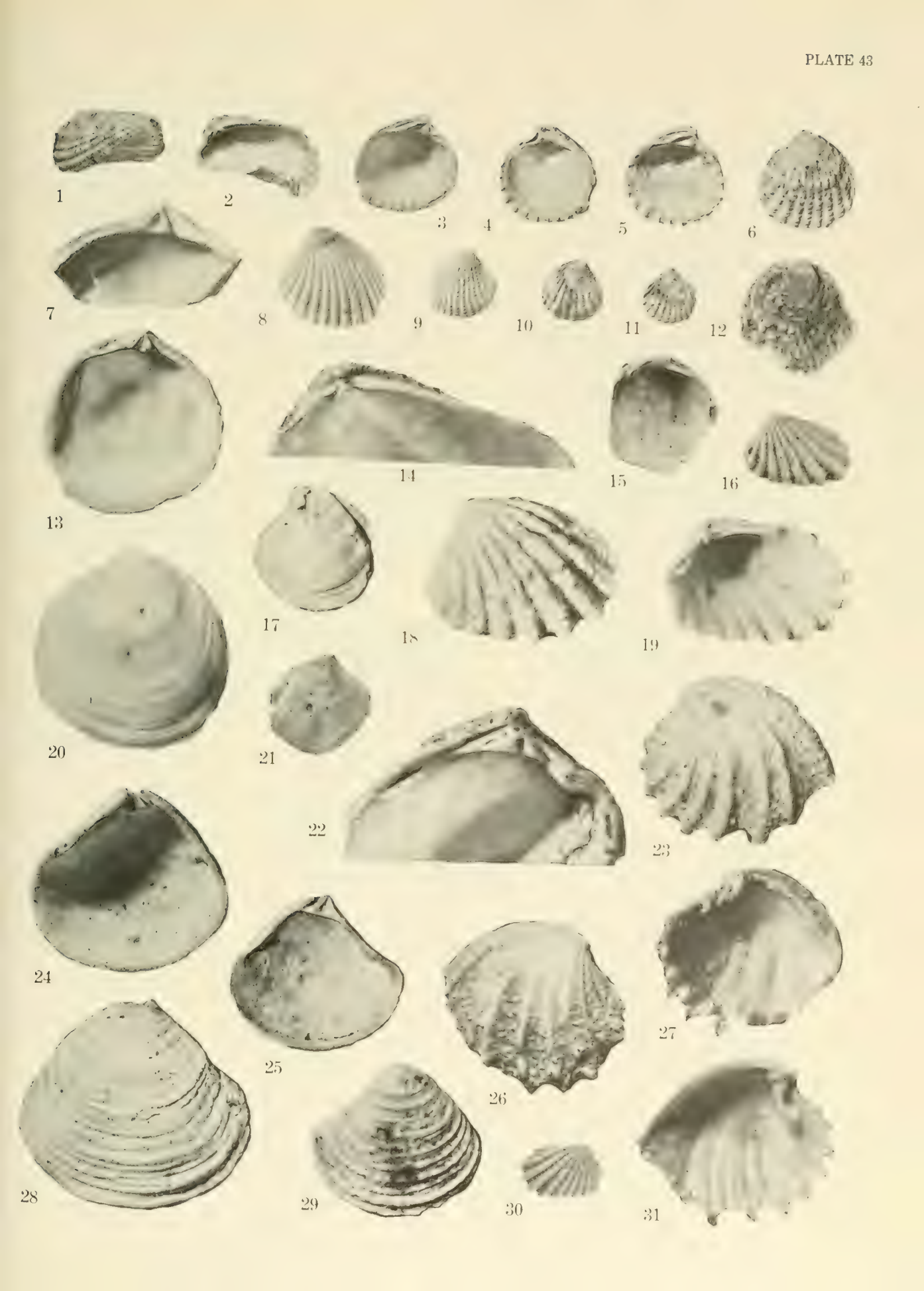
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PLATE 44

Fig. 1. *Aligena diegoana* n. sp. Paratype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM) at the same elevation. Length 6.3 mm.; height 5.3 mm. View of the exterior of a right valve. P. 235

Fig. 2. *Mysella tumida* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 2.4 mm.; height 2.0 mm. View of the exterior of a right valve. P. 239

Fig. 3. *Mysella tumida* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 2.3 mm.; height 1.8 mm. View of the exterior of a left valve. P. 239

Fig. 4. *Mysella tumida* Carpenter. View of the interior of the specimen shown in fig. 2.

Fig. 5. *Mysella tumida* Carpenter. View of the interior of the specimen shown in fig. 3.

Fig 6. *Aligena diegoana* n. sp. View of the interior of the specimen shown in fig. 1.

Fig 7. *Mysella tumida* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 2.9 mm.; height 2.1 mm. View of the interior of a left valve. P. 239

Fig. 8. *Mysella tumida* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 3.2 mm.; height 2.7 mm. View of the exterior of a left valve. P. 239

Fig. 9. *Pristes oblongus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3.4 mm.; height 2.6 mm.

Fig. 10. *Pristes oblongus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 2.9 mm.; height 2.3 mm. View of the interior of a right valve. P. 240

Fig. 11. *Kellia laperousii* Deshayes. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.0 mm.; height 3.3 mm. View of the interior of a left valve. P. 237

Fig. 12. *Mysella tumida* Carpenter. View of the exterior of the specimen shown in fig. 7.

Fig 13. *Pristes oblongus* Carpenter. View of the exterior of the specimen shown in fig. 9.

Fig. 14. *Pristes oblongus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3.0 mm.; height 2.6 mm. View of the interior of a left valve. P. 240

Fig. 15. *Petricola (Rupellaria) carditoides* Conrad. Hypotype (San Diego Society of Natural History), from Loc. 331 (SD), 200 feet north of the Mexican boundary and ¾ mile from the coast, exposure of strata of Pliocene age in east-west ravine tributary to a larger south-north ravine at right angle, in first terrace above the Tiajuana river plain. Length 29.8 mm.; height 15.7 mm. View of the exterior of a left valve. P. 283

Fig 16. *Petricola (Rupellaria) carditoides* Conrad. View of the interior of the specimen shown in fig. 15.

Fig 17. *Axinopsida serricata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3.5 mm.; height 3.3 mm. View of the interior of a left valve. P. 257

Fig 18. *Axinopsida serricata* Carpenter. View of the exterior of the specimen shown in fig. 17.

Fig 19. *Kellia laperousii* Deshayes. View of the exterior of the specimen shown in fig. 11.

Fig 20 *Transennella tantilla* Gould. Hypotype (Los Angeles County Museum), from Loc. 305C Length 3.7 mm.; height 3.0 mm. P. 282

Fig 21. *Psephidia stephensae* n. sp. Holotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3.0 mm.; height 2.7 mm. View of the interior of a right valve. P. 280

Fig 22. *Psephidia stephensae* n. sp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.7 mm.; height 2.6 mm. View of the interior of a right valve. P. 280

Fig 23. *Transennella tantilla* Gould. (Los Angeles County Museum), from the same locality as the specimen shown in fig. 27. Length 5.8 mm.; height 4.8 mm.

Fig 24. *Psephidia stephensae* n. sp. Holotype. View of the exterior of the specimen shown in fig. 21.

Fig 25. *Transennella tantilla* Gould. Hypotype (University of California at Los Angeles), from Loc. 1386 (UCLA), *Dosinia* beds in cut bank 338 feet farther along the ravine road (from Loc. 1385), just below the southeast corner of the Federal Building, Balboa Park, San Diego. Length 7.0 mm.; height 6.0 mm. View of the exterior of a left valve. P. 282

Fig 26. *Psephidia stephensae* n. sp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3.9 mm.; height 3.2 mm. View of the interior of a left valve. P. 280

Fig 27. Transennella tantilla Gould. Hypotype (Los Angeles County Museum), from Loc. 309 (LAM), two canyons east of Kate Sessions School; approximately 0.3 mile west of Balboa Avenue from U.S. Highway 101. Length 5.5 mm.; height 4.5 mm. View of the interior of a left valve. P. 282

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PLATE 45

Fig. 1 *Lucina (Lucinisca) nuttalli* Conrad. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co., (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 26.6 mm.; height 19.8 mm. View of the exterior of a right valve. P. 245

Fig. 2. *Lucina (Lucinisca) nuttalli* Conrad. View of the interior of the specimen shown in fig. 1.

Fig. 3. *Lucina (Lucinisca) nuttalli* Conrad. Hypotype (los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 25.8 mm.; height 18.9 mm. View of the exterior of a left valve.

Fig. 4. *Lucina (Lucinisca) nuttalli* Conrad. View of the interior of the specimen shown in fig. 3.

Fig. 5. *Pristes oblongus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3.3 mm.; height 3.0 mm. View of the exterior of a right valve. P. 239

Fig. 6. *Aligena diegoana* n. sp. Paratype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM) at the same elevation. Length 5.7 mm.; height 5.1 mm. View of the exterior of a right valve. P. 235

Fig. 7. *Aligena diegoana* n. sp. Holotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 7.9 mm.; height 6.1 mm. View of the interior of a right valve. P. 235

Fig. 8. *Pristes oblongus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.1 mm.; height 4.0 mm. View of the exterior of a left valve. P. 239

Fig. 9. *Pristes oblongus* Carpenter. View of the interior of the specimen shown in fig. 5.

Fig. 10. *Aligena diegoana* n. sp. Paratype from the same locality as the specimen shown in fig. 1. Length 8.0 mm.; height 6.4 mm. View of the interior of a left valve. P. 235

Fig. 11. *Aligena diegoana* n. sp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 8.5 mm.; height 6.7 mm. View of the exterior of a right valve. P. 235

Fig. 12. *Pristes oblongus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 3.2 mm.; height 2.7 mm. View of the exterior of a left valve. P. 239

Fig. 13. *Aligena diegoana* n. sp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 7.5 mm.; height 6.0 mm. View of the exterior of a right valve. P. 235

Fig. 14. *Miltha (Miltha) xantusi* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 6. Length 61.0 mm.; height 60.0 mm. View of the exterior of a left valve which has been bored by a predator. P. 250

Fig. 15. *Miltha (Miltha) xantusi* Dall. View of the interior of the specimen shown in fig. 14.

Fig. 16. *Miltha (Miltha) xantusi* Dall. Hypotype (California Academy of Sciences), from Loc. 1402 (CAS), on end of point between Cabrillo Canyon and a gulch about 100 meters south of the west end of Laurel Street bridge across Cabrillo Canyon, Balboa Park, San Diego. Length 72.5 mm.; height 68.8 mm. View of the exterior of a right valve. P. 250

Fig. 17. *Miltha (Miltha) xantusi* Dall. Hypotype (California Academy of Sciences), from the same locality as the specimen shown in fig. 16. Length 58.0 mm.; height 61.3 mm. View of a right valve, smaller and more ovate in outline than the specimen shown in fig. 16 P. 250

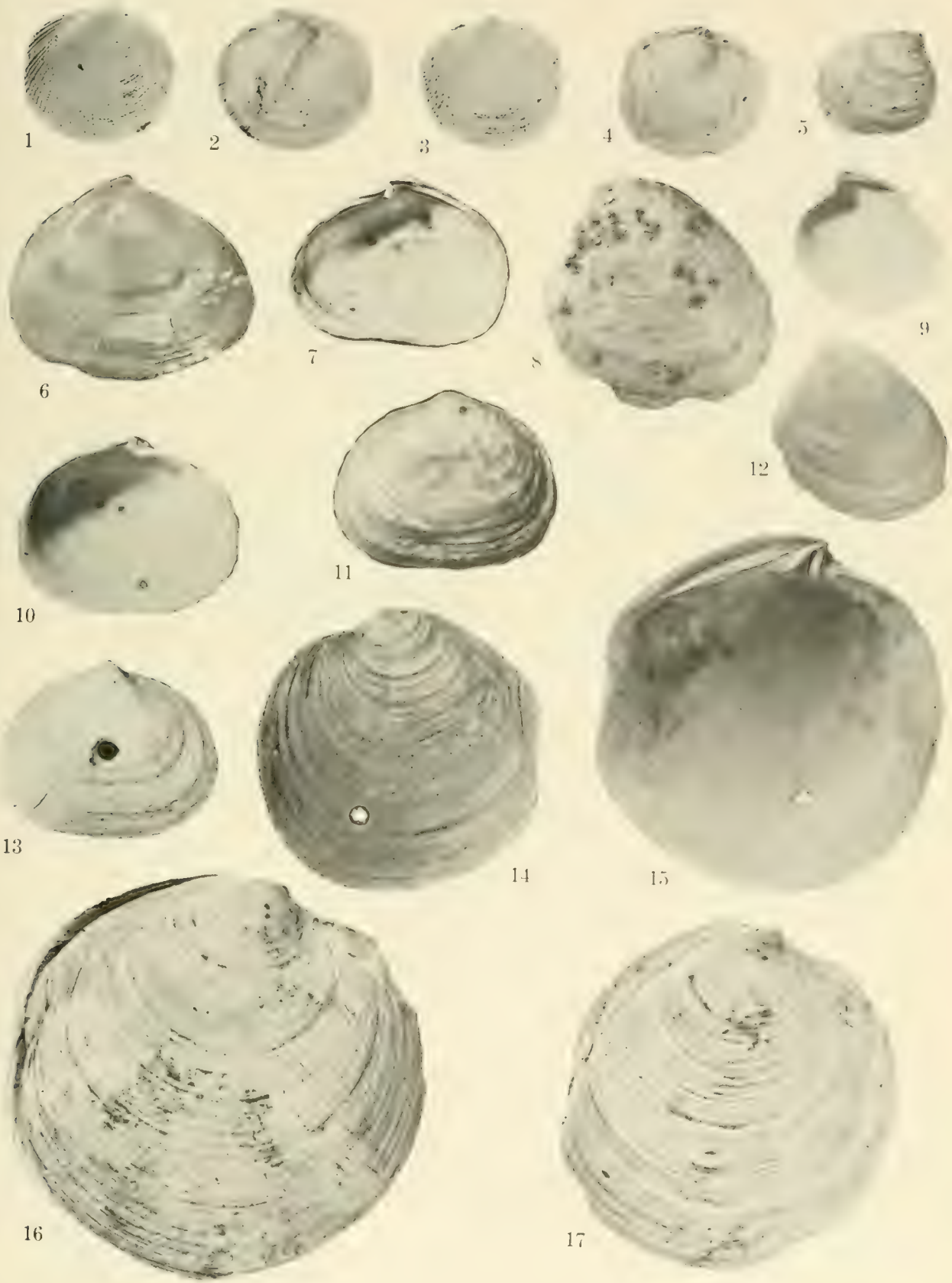
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PLATE 46

Fig. 1. *Lucina (Here) excavata* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co., (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 15.5 mm.; height 14.2 mm. View of the exterior of a left valve. P. 244

Fig. 2. *Lucina (Here) excavata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen illustrated in fig. 1. Length 17 mm.; height 17 mm. View of the interior of a left valve.

Fig. 3. *Lucina (Here) excavata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen illustrated in fig. 1. Length 19 mm.; height 19 mm. View of the interior of a right valve.

Fig. 4. *Nemocardium (Keenaea) centifilosum* Carpenter. Hypotype (San Diego Society of Natural History), from the corner of India and Upas streets, San Diego. Length 16 mm.; height 16 mm. View of the exterior of a right valve. P. 263

Fig. 5. *Nemocardium (Keenaea) centifilosum* Carpenter. View of the left valve of the specimen shown in fig. 4.

Fig. 6. *Lucina (Parvilucina) intensa* Dall. Syntype No. 698D (California Academy of Sciences), from the San Diego well, Balboa Park, San Diego. Length 7.7 mm.; height 6.5 mm. View of the exterior of a left valve. P. 247

Fig. 7. *Lucina (Parvilucina) intensa* Dall. View of the interior of the specimen shown in fig. 6.

Fig. 8. *Lucina (Lucinisca) nuttalli antecedens* Arnold. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 18.3 mm.; height 16.9 mm. View of the exterior of a right valve. P. 246

Fig. 9. *Lucina (Lucinisca) nuttalli antecedens* Arnold. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 17 mm.; height 15.3 mm. View of a left valve. P. 246

Fig. 10. *Nemocardium (Keenaea) centifilosum* Carpenter. Hypotype (California Academy of Sciences), from Loc. 12078 (CAS) San Diego well, Balboa Park, San Diego. Length 16.5 mm.; height 16.5 mm. View of the exterior of a right valve. P. 263

Fig. 11. *Lucina (Epilucina) californica* Conrad. Hypotype (San Diego Society of Natural History), from Loc. 80 (SD), middle part of gulch about 1/3 mile west of the mouth of Rose Canyon, south slope of Mount Soledad, San Diego. Length 13.4 mm.; height 13.5 mm. View of the exterior of a right valve. P. 247

Fig. 12. *Lucina (Lucinoma) annulata* Reeve. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 44.6 mm.; height 38.5 mm. View of the exterior of a right valve. P. 247

Fig. 13. *Lucina (Lucinisca) nuttalli antecedens* Arnold. View of the interior of the specimen shown in fig. 8.

Fig. 14. *Lucina (Lucinisca) nuttalli antecedens* Arnold. View of the interior of the specimen shown in fig. 9.

Fig. 15. *Nemocardium (Keenaea) centifilosum* Carpenter. View of the interior of the specimen shown in fig. 10.

Fig. 16. *Lucina (Epilucina) californica* Conrad. View of the interior of the specimen shown in fig. 11.

Fig. 17. *Lucina (Parvilucina) intensa* Dall. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), from west side of next gully east of Loc. 305 (LAM) at the same elevation. Length 6.0 mm.; height 5.3 mm. View of the exterior of a left valve. P. 247

Fig. 18. *Cardium (Dallocardia) quadragenarium* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length (incomplete) 60 mm.; height (incomplete) 49 mm. View of the interior dorsal portion of a right valve. P. 259

Fig. 19. *Lucina (Lucinoma) annulata* Reeve. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 60.8 mm.; height 56.9 mm. View of the interior of a right valve. P. 247

Fig. 20. *Cardium (Dallocardia) quadragenarium* Conrad. View of the exterior of the specimen shown in fig. 18.

Fig. 21. *Cardium (Clinocardium) nuttalli* Conrad. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), 100-foot bluff with fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego. Length 80 mm.; height 82.4 mm.

Fig. 22. *Lucina (Parvilucina) intensa* Dall. Hypotype (Los Angeles County Museum), from Loc. 318 (LAM), Knox Ranch hill, just above the gates and the cow shed; 200 feet from the road and 30 feet above the valley floor, near Mexican boundary. Length 6.4 mm.; height 6.9 mm. View of the interior of a right valve. P. 247

Fig. 23. *Cardium (Dallocardia) quadragenarium* Conrad. Hypotype (California Academy of Sciences), from Loc. 1402 (CAS), on end of point between Cabrillo Canyon and a gulch about 100 meters south of the west end of Laurel Street bridge across Cabrillo Canyon in Balboa Park, San Diego. Length 50 mm.; height 50.5 mm. View of the exterior of a left valve. P. 259

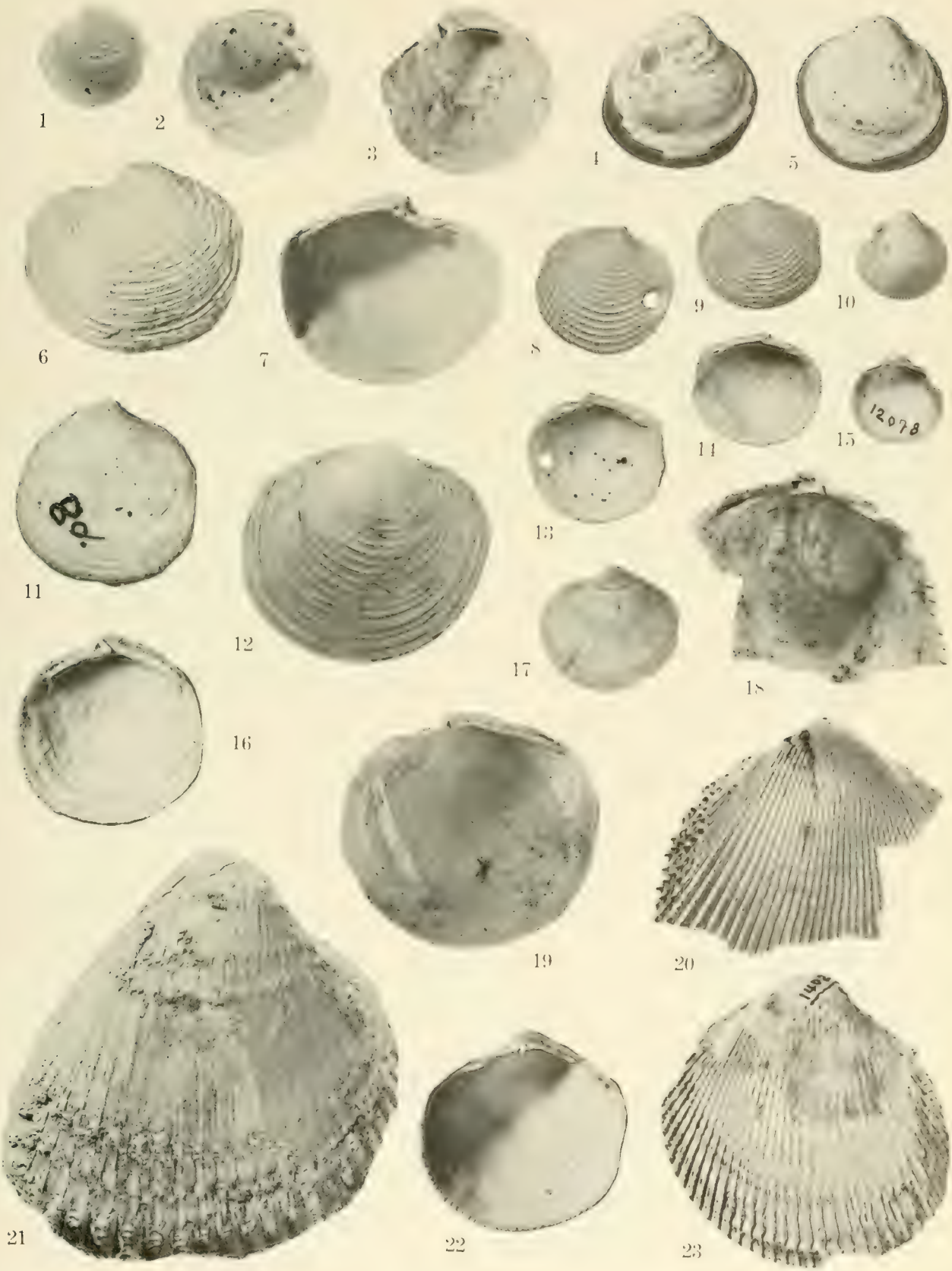
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PLATE 47

Fig. 1. *Pandora (Pandorella) bilirata* Conrad. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 13 mm.; height 7.5 mm. View of the interior of the specimen shown on Plate 48, fig. 14. P. 335

Fig. 2. *Dosinia (Dosinia) ponderosa diegoana* n. subsp. Paratype (California Academy of Sciences), from Loc. 1402 (CAS), on end of a point between Cabrillo Canyon and a gulch about 100 meters south of the west end of the Laurel Street bridge across Cabrillo Canyon, Balboa Park, San Diego. Length (incomplete) approximately 91.5 mm. View showing hinge of a left valve. P. 265

Fig. 3. *Dosinia (Dosinia) ponderosa diegoana* n. subsp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 114 mm.; height 111 mm. View of the interior of a right valve. P. 265

Fig. 4. *Compsomyax subdiaphana* Carpenter. Hypotype (California Academy of Sciences), from Loc. 1404 (CAS), southeast corner of India and Upas streets, San Diego. Length 41.6 mm.; height 35 mm. View of the exterior of the right valve. P. 269

Fig. 5. *Psephidia ovalis* Dall. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 4.2 mm.; height 3 mm. View of the exterior of a left valve shown on plate 51, fig. 9. P. 280

Fig. 6. *Dosinia (Dosinia) ponderosa diegoana* n. subsp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 117 mm.; height 120 mm. View showing dorsal area of a specimen. P. 265

Fig. 7. *Compsomyax subdiaphana* Carpenter. View showing the dorsal area of both valves of the specimen shown in fig. 4.

Fig. 8. *Dosinia (Dosinia) ponderosa diegoana* n. subsp. Holotype (California Academy of Sciences), from the same locality as the specimen shown in fig. 2. Length 121 mm.; height 130 mm. View of the exterior of the right valve. P. 265

Fig. 9. *Psephidia ovalis* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 5. Length 4.1 mm.; height 3.1 mm. View of the exterior of a right valve shown on plate 51, fig. 8. P. 280

Fig. 10. *Dosinia (Dosinia) ponderosa diegoana* n. subsp. View of the dorsal area of both valves of the holotype shown in fig. 8. P. 265

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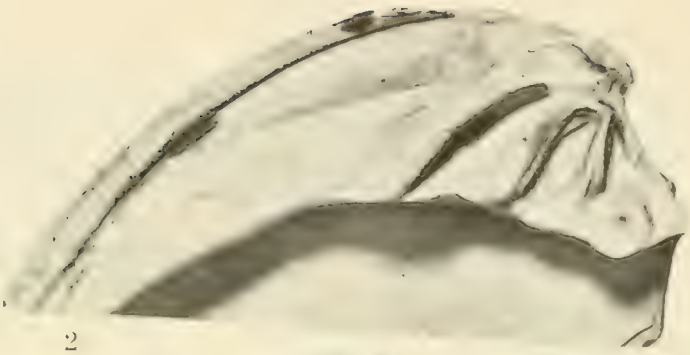

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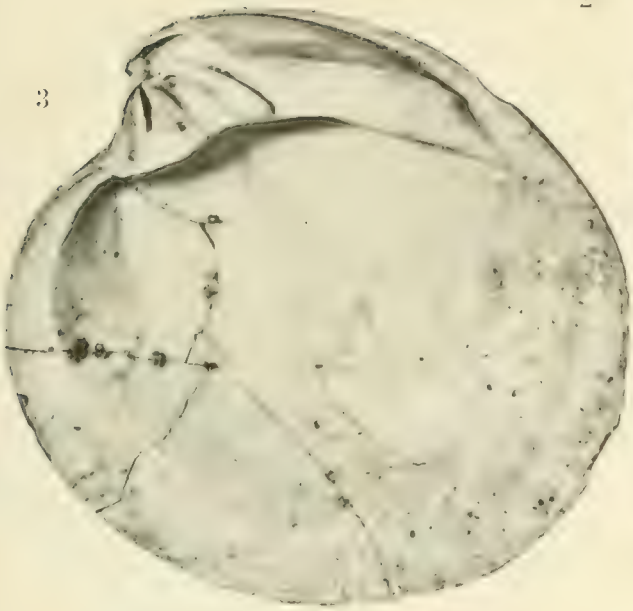

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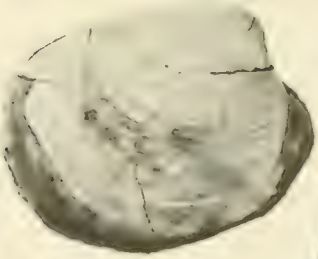

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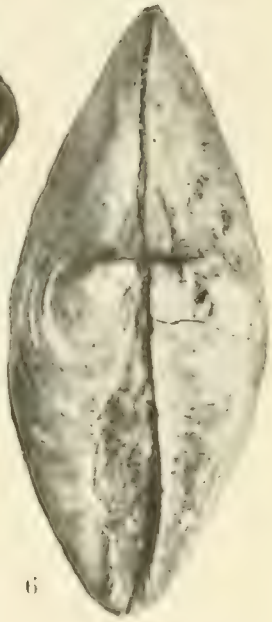

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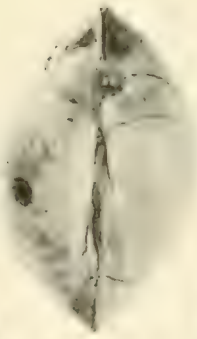

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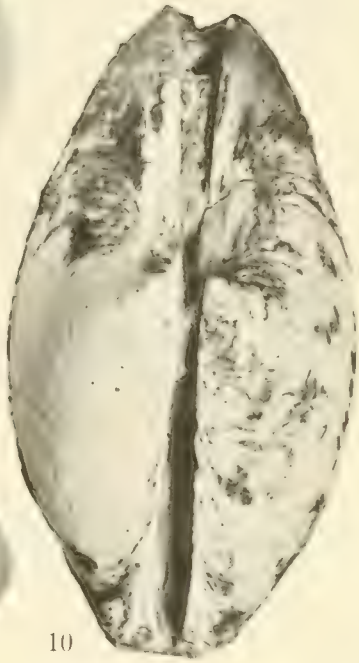

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PLATE 48

Fig. 1. *Semele rubropicta* Dall. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 42.5 mm.; height 35.5 mm. View of the exterior of a left valve. P. **300**

Fig. 2. *Semele rubropicta* Dall. View of the exterior of the right valve of the specimen shown in fig. 1.

Fig. 3. *Semele ashleyi* n. sp. Paratype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 29 mm.; height 23.6 mm.

Fig. 4. *Semele* species. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 5.5 mm.; height 4.4 mm. View of the exterior of a small right valve. This is probably a juvenile shell of *Semele ashleyi* n. sp. P. **299**

Fig. 5. *Semele ashleyi* n. sp. Holotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 40.5 mm.; height 37 mm. View of the exterior of the left valve. P. **299**

Fig. 6. *Semele ashleyi* n. sp. Holotype. View of the exterior of the right valve of the specimen shown in fig. 5.

Fig. 7. *Semele rubropicta* Dall. View of the dorsal area of the specimen shown in figs. 1 and 2. This view shows the small lunula-like area just anterior to the beaks. P. **300**

Fig. 8. *Semele* species. View of the interior of the specimen shown in fig. 4.

Fig. 9. *Semele ashleyi* n. sp. View of the interior of the specimen shown in fig. 5.

Fig. 10. *Semele ashleyi* n. sp. View of the interior of the specimen shown in fig. 6.

Fig. 11. *Semele rubropicta* Dall. Hypotype (Los Angeles County Museum), from Loc. 318 (LAM), Knox Ranch hill, just above the gates and cow shed; 200 feet from the road and 30 feet above the valley floor, southwestern San Diego Co. Length 45.4 mm.; height 37.6 mm. View of the interior of a right valve. P. **300**

Fig. 12. *Solen rosaceus* Carpenter. Hypotype (Cat. No. 5006, San Diego Society of Natural History), from Mount Soledad, San Diego. Length 29.0 mm.; height 8.0 mm. View of the exterior of a right valve. P. **308**

Fig. 13. *Gobraeus edentulus* Gabb. Hypotype (University of California at Los Angeles), from Loc. 2359 (UCLA), sandstone outcropping in a small canyon parallel to and about 0.2 mile west of the mouth of Rose Canyon and 0.4 mile north of Garnet Avenue, La Jolla quad., San Diego. Length 82.8 mm.; height 41 mm. View of the exterior of a right valve. P. **305**

Fig. 14. *Pandora (Pandorella) bilirata* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 3. Length 13.0 mm.; height 7.5 mm. View of the exterior of a right valve. P. **335**

Fig. 15. *Gobraeus edentulus* Gabb. Hypotype (University of California at Los Angeles), from the same locality as the specimen shown in fig. 13. Length 80.5 mm.; height 41 mm. View of the exterior of a left valve. P. **305**

Fig. 16. *Donax (Serrula) gouldii* Dall. Hypotype (University of California at Los Angeles), from Loc. 294 (UCLA), 200 feet north of the Mexican boundary and ¾ mile east of the coast; exposure of strata in east-west ravine, tributary to a larger south-north ravine at right angle, in first terrace above the Tiajuana River plain. Length 14.5 mm.; height 8.7 mm. View of the exterior of a right valve. P. **303**

Fig. 17. *Pandora (Pandorella) bilirata* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 3. Length 13.0 mm.; height 8.0 mm. View of the exterior of a left valve. P. **335**

Fig. 18. *Pandora (Pandorella) bilirata* Conrad. View of the interior of the specimen shown in fig. 17.

Fig. 19. *Donax (Serrula) gouldii* Dall. Hypotype (Los Angeles County Museum), from Loc. 319 (LAM), exactly between the United States-Mexico boundary fence and Mr. Ericson's (the manager's) house; 27 feet above the road level on the shoulder of the second hill. Length 14 mm.; height 9.8 mm. View of the interior of a right valve. P. **303**

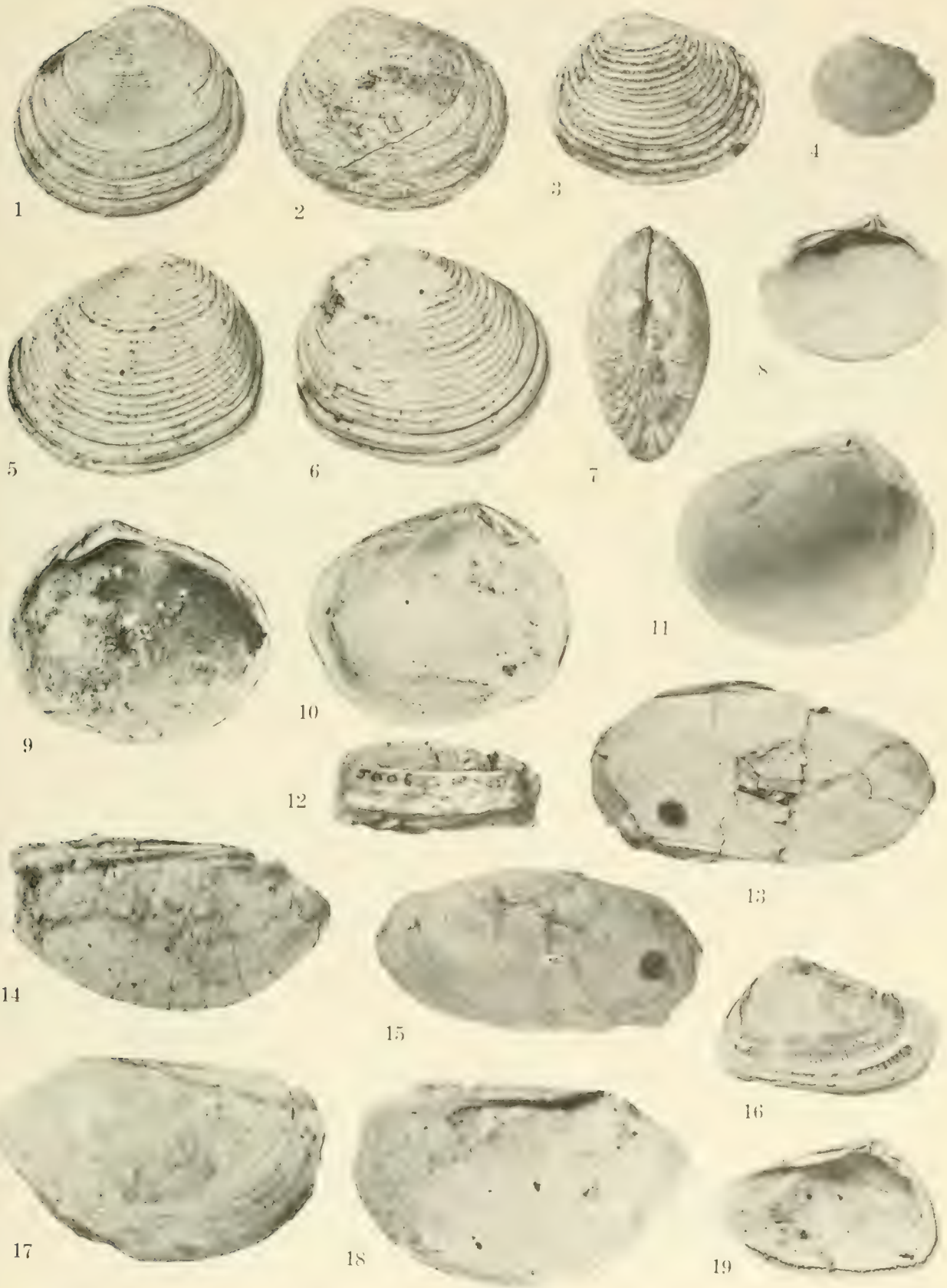
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PLATE 49

Fig. 1. *Chione (Securella) kanakoffi* n. sp. Paratype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length (of portion shown) approximately 97 mm. View of the hinge area of a left valve. P. 279

Fig. 2. *Siliqua lucida* Conrad. Hypotype (San Diego Society of Natural History), from Loc. 43 (SD), Reynard Way, San Diego. Length 38.2 mm.; height 16 mm. View of the exterior of a left valve. P. 311

Fig. 3. *Chione (Securella) kanakoffi* n. sp. Holotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 129 mm.; height 122 mm. View of the exterior of the right valve. P. 274

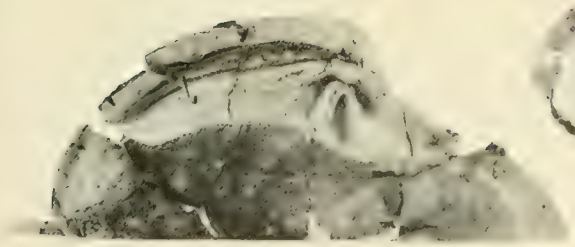
Fig. 4. *Chione (Securella) kanakoffi* n. sp. View of the dorsal area of the specimen shown in figs. 3 and 5.

Fig. 5. *Chione (Securella) kanakoffi* n. sp. View of the exterior of the left valve of the specimen shown in figs. 3 and 4.

Fig. 6. *Chione (Securella) kanakoffi* n. sp. Paratype (Los Angeles County Museum), from same locality as the specimen shown in fig. 3. Length 131 mm.; height 117 mm. View of the interior of a right valve. P. 274

Fig. 7. *Solen sicarius* Gould. Hypotype (Cat. No. 5005, San Diego Society of Natural History), gulch No. 4, south slope of Mount Soledad, San Diego. Length 63 mm.; height 16 mm. View of a left valve.

Fig. 8. *Dosinia (Dosinia) ponderosa diegoana* n. subsp. Paratype (California Academy of Sciences), from Loc. 1402 (CAS), on end of point between Cabrillo Canyon and a gulch about 100 meters south of the west end of Laurel Street bridge, across Cabrillo canyon, Balboa Park, San Diego. Length of area shown approximately 81.5 mm. View of the hinge area of a right valve. P. 265



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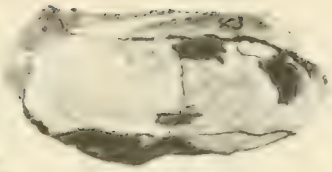

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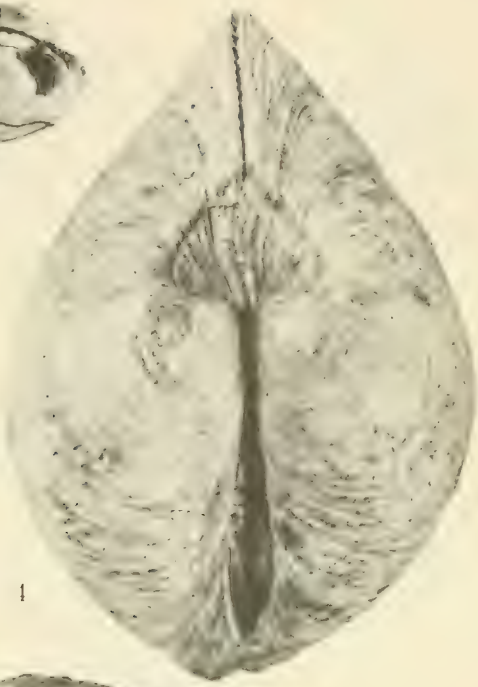

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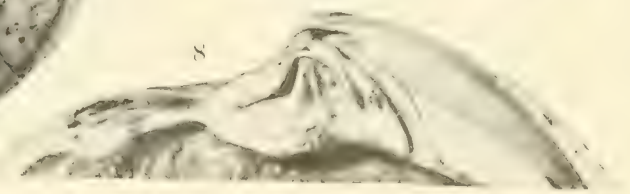

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PLATE 50

Fig. 1. *Megapitaria squalida* Sowerby. Hypotype (Los Angeles County Museum), from Loc. 302 (LAM), exposure of strata across the street from the house at 2840 Columbia Street, San Diego. Length 38.3 mm.; height 29.6 mm. View of the interior of a left valve. P. 268

Fig. 2. *Megapitaria squalida* Sowerby. From the same locality as the specimen shown in fig. 1. Length 46.2 mm.; height 35.5 mm. View of the exterior of a right valve. P. 268

Fig. 3. *Megapitaria squalida* Sowerby. View of the interior of the specimen shown in fig. 2.

Fig. 4. *Tivela (Pachydesma) stultorum* Mawe. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), second ravine north of Loc. L-294 (UCLA) and fifth ravine north (about ¼ mile) of the Mexican boundary, at west face of a terrace ¾ mile from the coast. Length 48 mm.; height 35 mm. View of the interior of a right valve. P. 266

Fig. 5. *Tivela (Pachydesma) stultorum* Mawe. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 96.8 mm.; height 73 mm. View of the exterior of a left valve. P. 266

Fig. 6. *Tivela (Pachydesma) stultorum* Mawe. View of the interior of the specimen shown in fig. 5.

Fig. 7. *Macoma (Rexithaerus) indentata tenuirostris* Dall. Hypotype (San Diego Society of Natural History, from Loc. 331 (SD), 200 feet north of the Mexican boundary and ¾ mile from the coast, an exposure of strata of Pliocene age in an east-west ravine tributary to a larger south-north ravine at right angle, in first terrace above the Tiajuana River plain. Length 27.3 mm.; height 16.3 mm. View of the exterior of a left valve. P. 297

Fig. 8. *Saxidomus nuttalli latus* Stewart. Hypotype (California Academy of Sciences), from Loc. 12051 (H. Hemphill Coll.), from San Diego well. Length (incomplete) 118 mm.; height (incomplete) 79 mm. View of the interior of a right valve. P. 272

Fig. 9. *Saxidomus nuttalli* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 4. Length 97.5 mm.; height 75.5 mm. View of the exterior of a left valve.

Fig. 10. *Saxidomus nuttalli latus* Stewart. View of the exterior of the specimen shown in fig. 8.

Fig. 11. *Irusella lamellifera* Conrad. Hypotype (University of California at Los Angeles), from Loc. 298 (UCLA), lowest *Pecten healeyi* bed, from just south of a ravine which is immediately south of the contact between the Eocene and the Pliocene strata, Pacific Beach. Length 27.4 mm. View of the exterior of a right valve, the apical area incomplete. P. 279

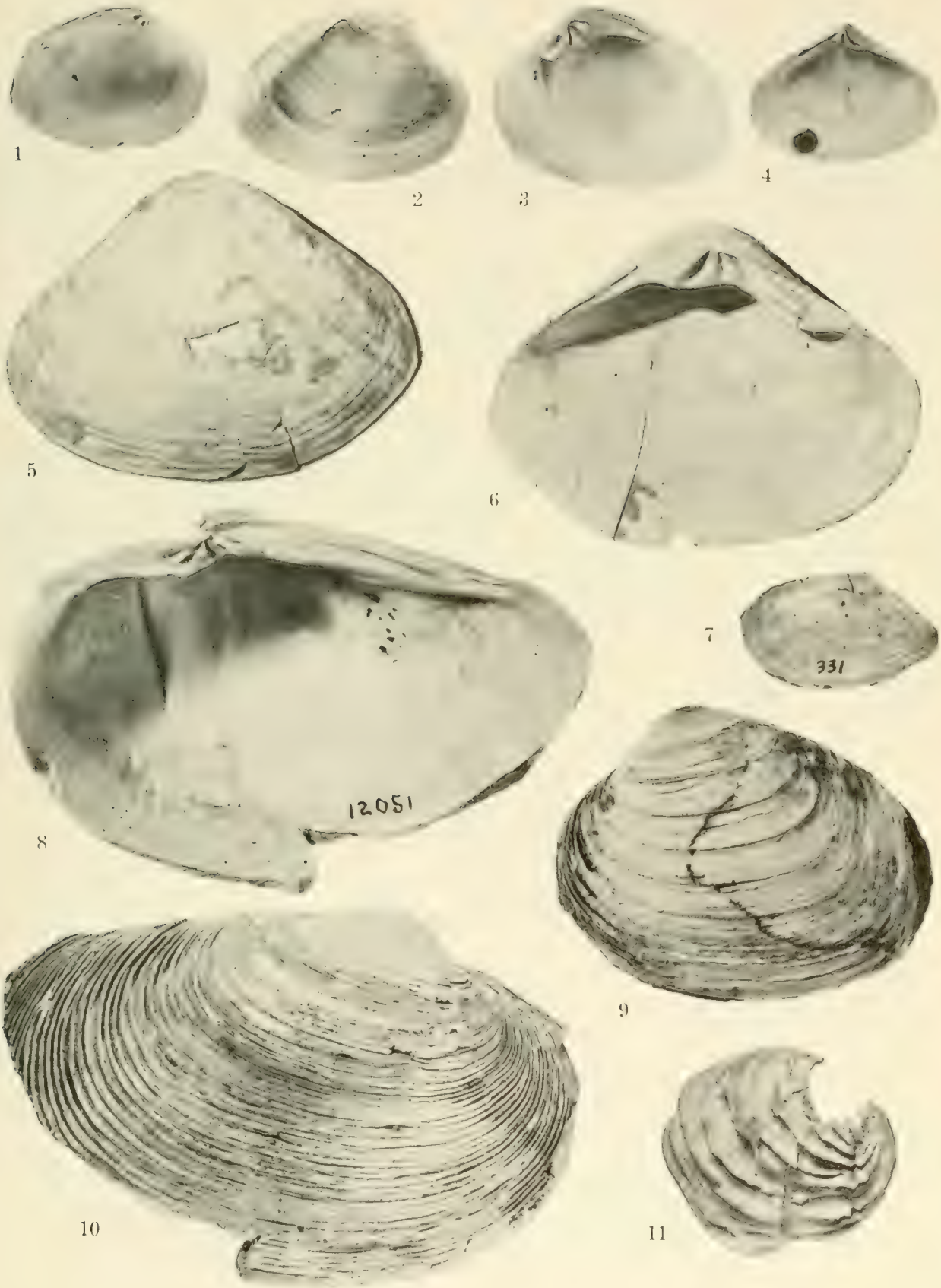
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PLATE 51

Fig. 1. *Protothaca (Callithaca) tenerrima* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of gully next east of Loc. 305 (LAM), at the same elevation. Length of dorsal portion of the specimen, 56 mm. P. 277

Fig. 2. *Protothaca (Callithaca) tenerrima* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 49.4 mm.; height 37 mm. View of the interior of a left valve. P. 277

Fig. 3. *Protothaca (Callithaca) tenerrima* Carpenter. Hypotype (California Academy of Sciences), from Loc. 1402 (CAS), on end of point between Cabrillo Canyon and a gulch about 100 meters south of the west end of Laurel Street bridge across Cabrillo Canyon, Balboa Park, San Diego. Length of portion of specimen, approximately 98.0 mm. View of the hinge area of a right valve. P. 277

Fig. 4. *Chione (Securella) kanakoffi* n. sp. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 17.7 mm.; height 18 mm. View of the exterior of a juvenile left valve.

Fig. 5. *Chione (Securella) kanakoffi* n. sp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 19 mm.; height 16.5 mm. View of the exterior of a juvenile right valve. P. 274

Fig. 6. *Chione (Securella) kanakoffi* n. sp. View of the interior of the specimen shown in fig. 4.

Fig. 7. *Chione (Securella) kanakoffi* n. sp. View of the interior of the specimen shown in fig. 5.

Fig. 8. *Psephidia ovalis* Dall. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 4.1 mm.; height 3.1 mm. View of the interior of the right valve shown on plate 47, fig. 9. P. 280

Fig. 9. *Psephidia ovalis* Dall. Hypotype ((Los Angeles County Museum), from the same locality as the specimen shown in fig. 8. Length 4.2 mm.; height 3 mm. View of the interior of the left valve shown on plate 47, fig. 5.

Fig. 10. *Chione (Securella) kanakoffi* n. sp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 2. Length 131 mm.; height 117 mm. View of the exterior of the specimen shown on plate 49, fig. 6.

Fig. 11. *Chione (Chione) allisoni* n. sp. Paratype (San Diego Society of Natural History), from Loc. 223 (SDSC), shell bed at base of cut and about 5 feet stratigraphically lower than Loc. 222 (SDSC). Length 27.5 mm.; height 25.8 mm. View of the exterior of a left valve showing the comparatively fine radial ribbing and close concentric lamellae. P. 273

Fig. 12. *Chione (Chione) allisoni* n. sp. Paratype (San Diego Society of Natural History), from the same locality as the specimen shown in fig. 11. Length 27.5 mm.; height 25.2 mm. View of the interior of a right valve.

Fig. 13. *Chione (Chione) allisoni* n. sp. View of the exterior of the specimen shown in fig. 12.

Fig. 14. *Dosinia (Dosinia) ponderosa diegoana* n. subsp. Paratype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 2. Length 117 mm.; height 119 mm. View of the exterior of the right valve of the specimen shown on plate 47, fig. 6, which has been bored by a gastropod.

Fig. 15. *Chione (Chione) allisoni* n. sp. Holotype (San Diego Society of Natural History), from Loc. 222 (SDSC), shell bed exposed at middle of south facing cut bank on corner lot at northeast corner of intersection of unnamed new streets, one of which is west of and parallel to Mount Soledad Road, the other (dead end) extends east of the first and is one block north of Kate Sessions Elementary School, San Diego. Length 32.6 mm.; height 27.2 mm. View of the exterior of a left valve. P. 273

Fig. 16. *Chione (Chione) allisoni* n. sp. View of the interior of the specimen shown in fig. 15.

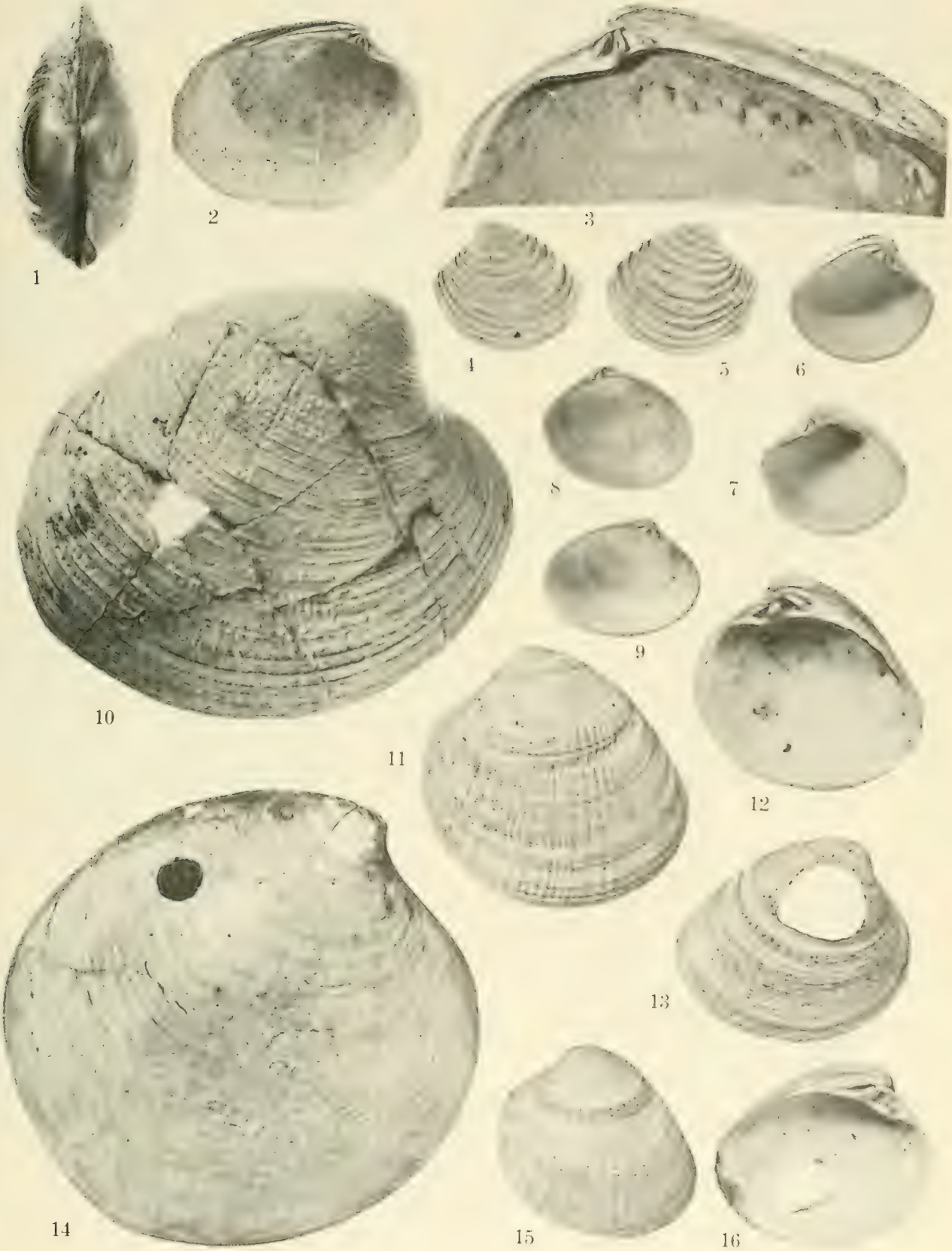
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PLATE 52

Fig. 1. *Macoma (Macoma) inquinata* Deshayes. Hypotype (Los Angeles County Museum), from Loc. 124 (LAM), shell and echini stratum 15 feet below level of floor of Snyder's Continuation School. Length 33.3 mm.; height 25 mm. View of the interior of a left valve. P. 292

Fig. 2. *Macoma (Rexithaerus) indentata tenuirostris* Dall. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM) at the same elevation. Length 41.8 mm.; height 24.5 mm. View of the exterior of a right valve. P. 297

Fig. 3. *Macoma (Rexithaerus) indentata* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 319 (LAM), exactly between the United States-Mexico boundary fence and Mr. Ericson's (the manager's) house, 27 feet above the road level on the shoulder of the second hill. Length 46 mm.; height 31 mm. View of the exterior of a right valve.

Fig. 4. *Macoma (Rexithaerus) indentata* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 35.5 mm.; height 23.6 mm. View of the exterior of a right valve. P. 296

Fig. 5. *Macoma (Macoma) nasuta kelseyi* Dall. Hypotype (Cat. No. 5679 San Diego Society of Natural History), from Cholla Valley, San Diego. Length 86 mm.; height 61 mm. View of the interior of a left valve. P. 294

Fig. 6. *Macoma (Macoploma) medioamericana* Pilsbry and Olsson. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 2. Length 60.4 mm.; height 34 mm. View of the exterior of a left valve. P. 295

Fig. 7. *Macoma (Rexithaerus) indentata* Carpenter. View of the interior of the specimen shown in fig. 4.

Fig. 8. *Macoma (Macoploma) medioamericana* Pilsbry and Olsson. View of the interior of the specimen shown in fig. 6.

Fig. 9. *Macoma (Macoma) nasuta kelseyi* Dall. Hypotype (San Diego Society of Natural History), from the same locality as the specimen shown in fig. 5. Length 85.8 mm.; height 58 mm. View of the interior of a right valve. Note the difference in the shape of the pallial sinus shown in this valve as compared to that in the left valve in fig. 5. P. 294

Fig. 10. *Macoma (Macoma) inquinata* Deshayes. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 44 mm.; height 32.8 mm. View of the exterior of a right valve. P. 292

Fig. 11. *Macoma (Macoma) nasuta kelseyi* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 84 mm.; height 60.5 mm. View of the exterior of a left valve. P. 294

Fig. 12. *Macoma (Macoma) nasuta kelseyi* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 107 mm.; height 77 mm. View of the exterior of a right valve. P. 294

Fig. 13. *Protothaca (Callithaca) tenerrima* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at the base of a hill 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Surv. topog. map, San Ysidro quad., revision 1953). Length 126 mm.; height 92.5 mm. View of the exterior of a left valve. P. 277

Fig. 14. *Protothaca (Callithaca) tenerrima* Carpenter. View of the interior of the dorsal area of the specimen shown in fig. 13.

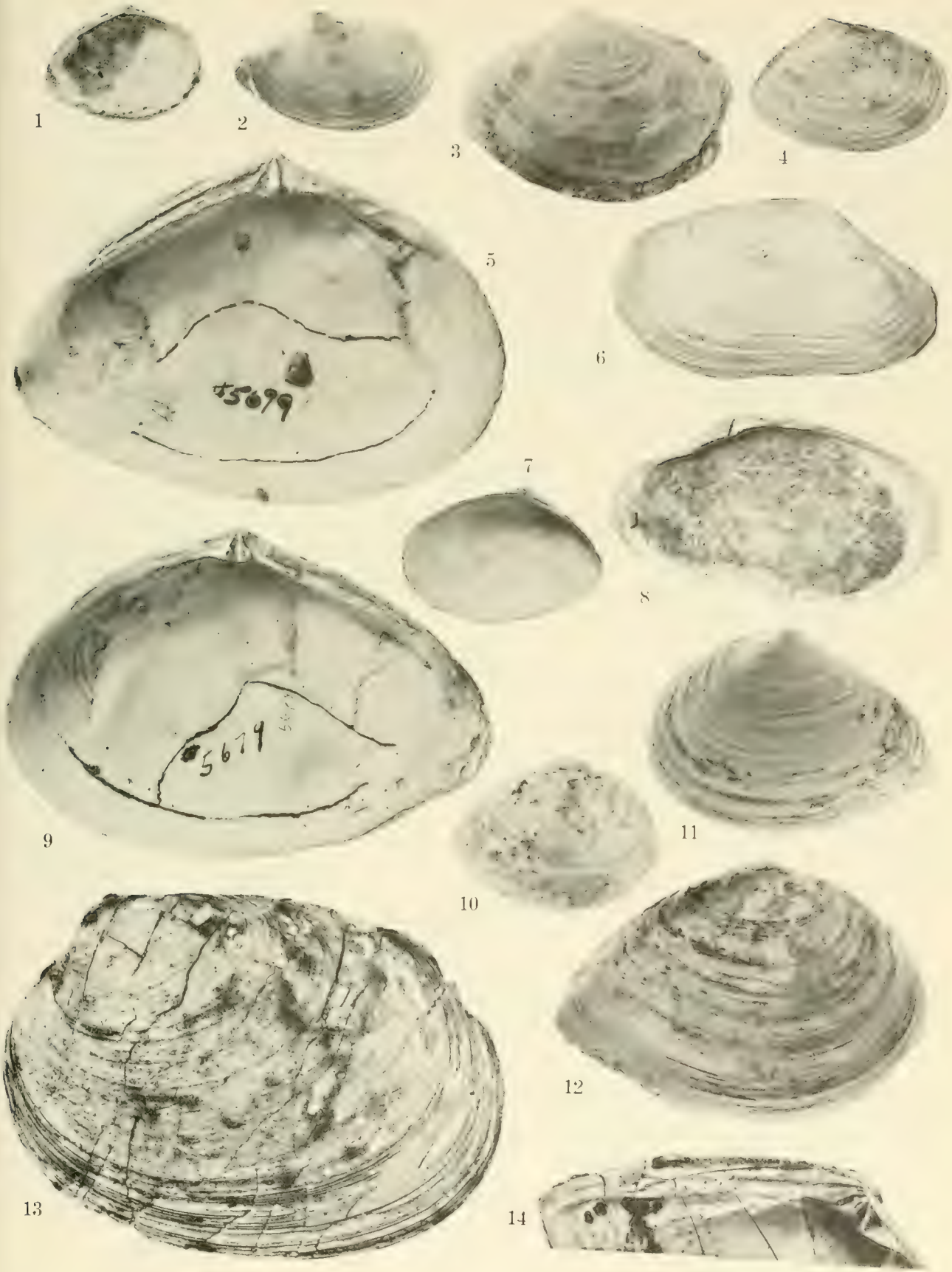
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PLATE 53

Fig. 1. *Tellina (Moerella) carpenteri* Dall. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1953). Length of area shown, approximately 9 mm.

Fig. 2. *Tellina (Cadella) salmonea* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length of area shown approximately 5.0 mm. View of the hinge area of a left valve. P. 286

Fig. 3. *Tellina (Cadella) salmonea* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 9.2 mm.; height 6.4 mm. View of the exterior of a right valve. P. 286

Fig. 4. *Tellina (Cadella) salmonea* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 8.0 mm.; height 5.9 mm. View of the exterior of a left valve.

Fig. 5. *Macoma (Macoma) elimata* Dunnill and Coan. Hypotype (University of California at Los Angeles), from Loc. 2359 (UCLA), sandstone outcropping in a small canyon parallel to and about two tenths of a mile west of the mouth of Rose Canyon and 0.4 mile north of Garnet Avenue, La Jolla quad. Length 27.7 mm.; height 27.8 mm. View of the exterior of a right valve. P. 291

Fig. 6 *Tellina (Tellinella) idae* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 57.3 mm.; height 33.5 mm. View of the exterior of a right valve. P. 285

Fig. 7 *Tellina (Moerella) carpenteri* Dall. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM), at the same elevation. Length 16.0 mm.; height 9.0 mm. View of the exterior of a right valve. P. 288

Fig. 8. *Tellina (Cadella) salmonea* Carpenter. View of the hinge area of the specimen shown in fig. 3.

Fig. 9. *Tellina (Peronidia) bodegensis* Hinds. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 51.8 mm.; height 25.5 mm. View of the exterior of a left valve. P. 289

Fig. 10. *Macoma (Macoma) nasuta* Conrad. Hypotype (California Academy of Sciences), from Loc. 1178 (CAS), bluff at foot of Garnet Avenue, Pacific Beach. Length 30 mm.; height 21.3 mm. View of the exterior of a right valve. P. 293

Fig. 11. *Tellina (Tellinella) idae* Dall. View of the interior of the specimen shown in fig. 6.

Fig. 12. *Macoma (Macoma) acolasta* Dall. Hypotype (University of California at Los Angeles), from Loc. 1386 (UCLA), *Dosinia* beds in cut bank 338 feet farther along the ravine road (from Loc. 1385) and just below the southeast corner of the Federal Building, Balboa Park, San Diego. Length 25.6 mm.; height 15.4 mm. View of the exterior of a right valve. P. 290

Fig. 13. *Macoma (Macoma) acolasta* Dall. View of the exterior of the left valve of the specimen shown in fig. 12.

Fig. 14. *Florimetis biangulata* Carpenter. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), second ravine north of Loc. 294 (UCLA) and fifth ravine north (about ¼ mile) of the Mexican boundary at west face of a terrace ¾ mile east of the coast. Length 108 mm.; height 83.5 mm. View of the exterior of a right valve. P. 298

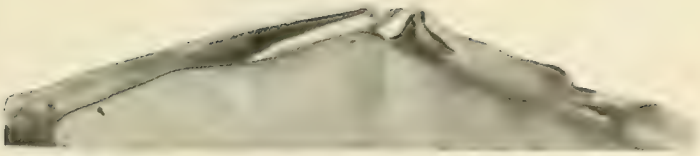
Fig. 15. *Tellina (Moerella) carpenteri* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1.

Fig. 16. *Tellina (Cadella) salmonea* Carpenter. View of the interior of the specimen shown in fig. 3.

Fig. 17. *Florimetis biangulata* Carpenter. View of the interior of the specimen shown in fig. 14.

Fig. 18. *Tellina (Peronidia) bodegensis* Hinds. Hypotype (University of California at Los Angeles), from the same locality as the specimen shown in fig. 14. Length 38 mm.; height 28.4 mm. View of the exterior of a right valve. P. 289

Fig. 19. *Florimetis biangulata* Carpenter. Hypotype (University of California at Los Angeles), from the same locality as the specimen shown in fig. 14. Length 64.4 mm.; height 57.3 mm. View of the exterior of a left valve. P. 298



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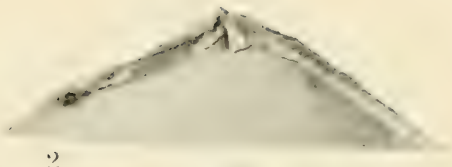

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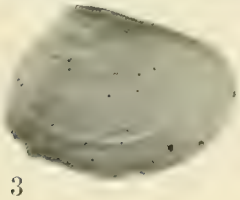

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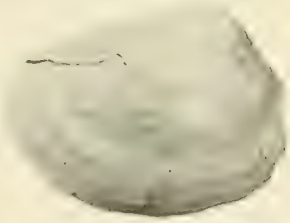

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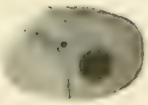

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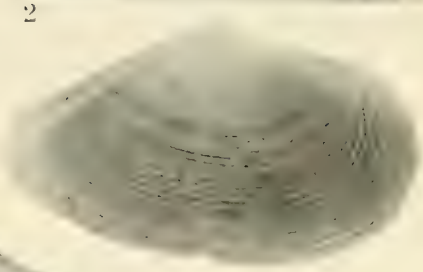

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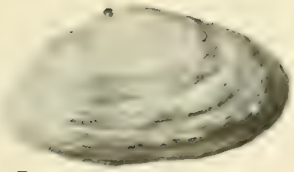

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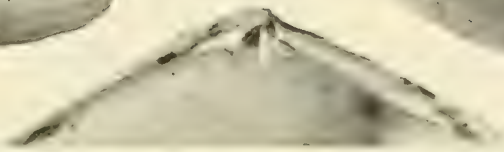

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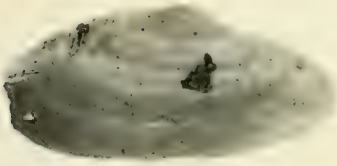

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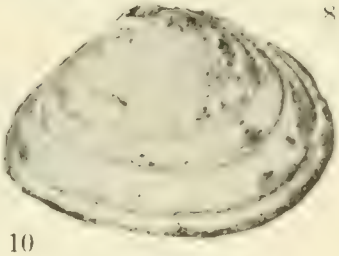

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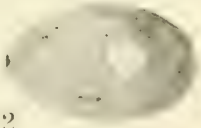

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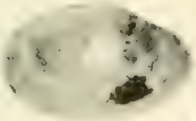

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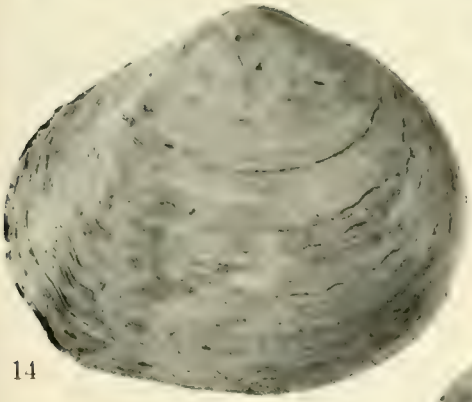

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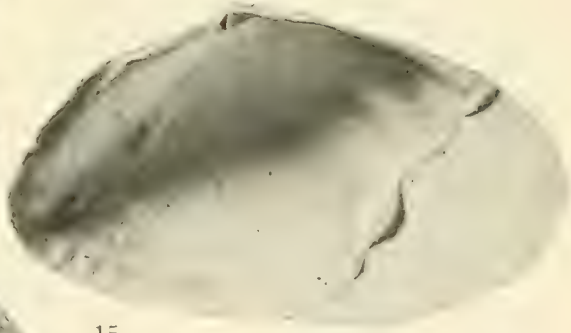

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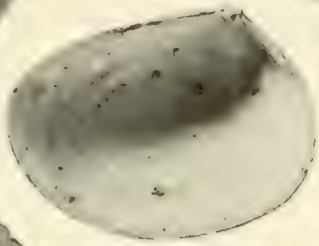

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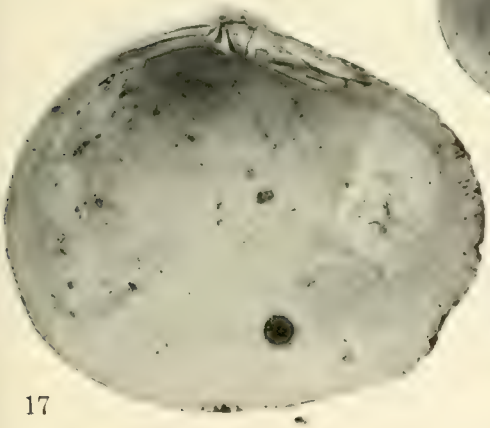

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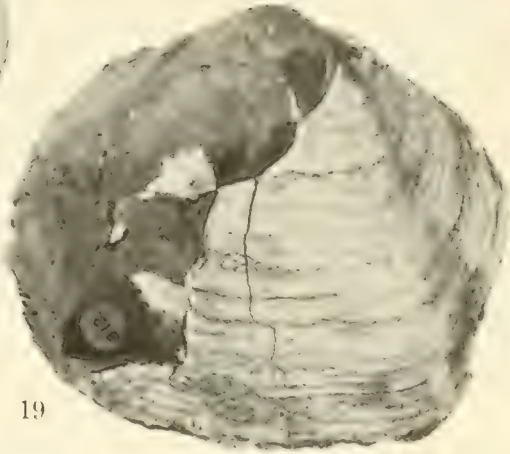

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PLATE 54

Fig. 1 *Spisula (Mactromeris) hemphillii* Dall. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 112 mm.; height 87 mm. View of the exterior of a right valve. P. **315**

Fig. 2. *Spisula (Mactromeris) hemphillii* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Portion (47 mm. long) of a left valve showing hinge area.

Fig. 3. *Spisula (Mactromeris) hemphillii* Dall. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM) at the same elevation. Length 123.6 mm.; height 94 mm. View of the exterior of a left valve. P. **315**

Fig. 4. *Spisula (Mactromeris) hemphillii* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 3. Portion (35.5 mm. long) of a right valve showing the hinge area. P. **315**

Fig. 5. *Spisula (Mactromeris) catilliformis* Conrad. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), 100-foot bluff with fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego. Length 91.6 mm.; height 74 mm. View of the exterior of a right valve. P. **313**

Fig. 6 *Macoma (Macoma) nasuta* Conrad. Hypotype (California Academy of Sciences), from Loc. 1178 (CAS), bluff at foot of Diamond Street, Pacific Beach. Length 21.5 mm.; height 30 mm. View of left valve of the specimen shown on plate 53, fig. 10. P. **293**

Fig. 7. *Spisula (Mactromeris) catilliformis* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 124 mm.; height 102 mm.

Fig. 8 *Spisula (Mactromeris)* cf. *S. (M.) falcata* Gould. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 3. Length 18 mm.; height 11.6 mm. View of the exterior of a juvenile left valve. P. **314**

Fig. 9 *Spisula (Mactromeris) hemphillii* Dall. Hypotype (Cat. No. 2946, San Diego Society of Natural History), Reynard Way, San Diego. Length 134.5 mm.; height 102 mm. View of the exterior of a left valve. P. **315**

Fig. 10. *Cryptomya californica magna* Dall. Hypotype (California Academy of Sciences), from Loc. 1402 (CAS), on end of point between Cabrillo Canyon and a gulch about 100 meters south of the west end of Laurel Street bridge across Cabrillo Canyon in Balboa Park, San Diego. View of chondrophore of a left valve. Area illustrated approximately 20 mm. long. P. **320**

Fig. 11. *Tresus nuttallii* Conrad. View of the interior of the juvenile specimen shown on plate 55, fig. 9.

Fig. 12. *Spisula (Mactromeris) mercedensis* Packard. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 5. Length 136 mm.; height 93 mm. View of a left valve.

Fig. 13. *Cryptomya californica magna* Dall. Hypotype (California Academy of Sciences), from the same locality as the specimen shown in fig. 10. Length 49.5 mm.; height 35 mm. View of the exterior of a left valve. P. **320**

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PLATE 55

Fig. 1. *Corbula luteola* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., ed. 1943). Length 7.8 mm.; height 5.0 mm. View of the exterior of a left valve. P. 324

Fig. 2. *Corbula luteola* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 8.1 mm.; height 5.6 mm. View of the exterior of a right valve. P. 329

Fig. 3. *Cryptomya californica* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 16.4 mm.; height 12.2 mm. View of the interior of a somewhat rostrate right valve. P. 319

Fig. 4. *Cryptomya californica* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 11.2 mm.; height 8.4 mm. View of the exterior of a right valve. P. 319

Fig. 5. *Corbula luteola* Carpenter. View of the interior of the specimen shown in fig. 1.

Fig. 6. *Corbula luteola* Carpenter. Hypotype from the same locality as the specimen shown in fig. 1. Length 7.9 mm.; height 5.4 mm. View of the interior of a right valve.

Fig. 7. *Cryptomya californica* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 13.0 mm.; height (incomplete) 10.8 mm. View of the exterior of a rounded left valve. P. 319

Fig. 8. *Cryptomya californica magna* Dall. Hypotype (California Academy of Sciences), from Loc. 1402 (CAS), on end of point between Cabrillo Canyon and a gulch about 100 meters south of the west end of Laurel Street bridge across Cabrillo Canyon in Balboa Park, San Diego. Length 44 mm.; height 31.5 mm. View of the exterior of a right valve and a portion of the ventral margin of the opposite valve. P. 320

Fig. 9. *Tresus nuttallii* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 38 mm.; height 25 mm. View of the exterior of a juvenile right valve. P. 318

Fig. 10. *Cryptomya californica* Conrad. View of the exterior of the specimen shown in fig. 3.

Fig. 11. *Diplodonta (Diplodonta) orbella* Gould. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length (incomplete) 12.5 mm.; height 11.4 mm. View of the exterior of a somewhat elongated, juvenile left valve. P. 252

Fig. 12. *Cryptomya californica magna* Dall. View of the left valve of the specimen shown in fig. 8.

Fig. 13. *Tresus nuttallii* Conrad. Hypotype (University of California at Los Angeles), from Loc. 2420 (UCLA), bluffs along Pacific Beach about ½ mile southeast of False Point, La Jolla quad. Length 104 mm.; height 73 mm. View of the exterior of a left valve. P. 318

Fig. 14. *Tresus nuttallii* Conrad. View of the exterior of the right valve of the specimen shown in fig. 13.

Fig. 15. *Corbula luteola* Carpenter. View of the dorsal area of the specimen of which the right valve is shown in fig. 6, the left valve in fig. 1.

Fig. 16. *Cryptomya californica* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 17.3 mm.; height 12.3 mm. View of the exterior of a right valve. P. 319

Fig. 17. *Tresus nuttallii* Conrad. View of the dorsal area of the specimen shown in figs. 13, 14.

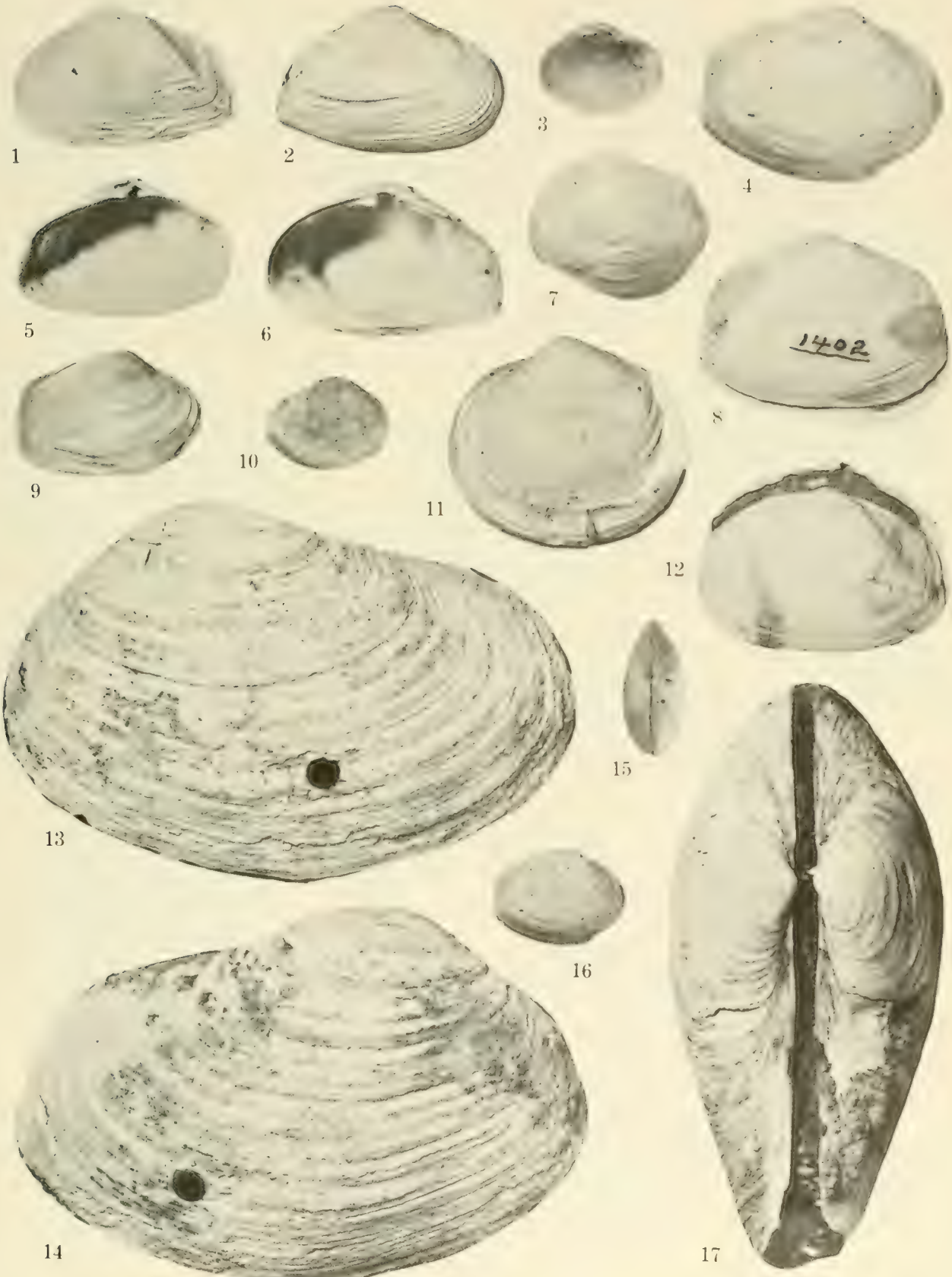
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PLATE 56

Fig. 1. *Miodontiscus prolongatus* Carpenter. Hypotype (Los Angeles County Museum), from Loc. 323 (LAM), under bridge between Fifth Street and the Radio Station, about 160 feet from the fence and about 350 feet from the Radio Station, San Diego. Length 6.7 mm.; height 7.8 mm. View of the exterior of a left valve. P. 233

Fig. 2. *Miodontiscus prolongatus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.9 mm.; height 5.9 mm. View of the interior of a right valve. P. 233

Fig. 3. *Miodontiscus prolongatus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.6 mm.; height 4.9 mm. View of this interior of a left valve. P. 233

Fig. 4. *Miodontiscus prolongatus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 5.3 mm.; height 5.8 mm. View of the exterior of a right valve. P. 233

Fig. 5. *Miodontiscus prolongatus* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 4.7 mm.; height 5.2 mm. View of the exterior of a right valve. P. 233

Fig. 6. *Dermatomya tenuiconcha* Dall. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad. ed. 1943). Length 9.7 mm.; height 8.2 mm. View of the exterior of a right valve. P. 341

Fig. 7. *Dermatomya tenuiconcha* Dall. View of the exterior of the left valve of the specimen shown in fig. 6.

Fig. 8. *Penitella penita* Conrad. Hypotype (San Diego Society of Natural History), from Loc. 417 (SD), second ravine north of Loc. 331 (SD) and fifth ravine north (about ¼ mile) of the Mexican boundary at west face of the terrace, about ¾ mile from the coast. Length 52.3 mm.; height 28.5 mm. View of the exterior of a left valve. P. 333

Fig. 9. *Penitella penita* Conrad. Hypotype (University of California at Los Angeles), from Loc. 312 (UCLA), same locality as the specimen shown in fig. 8. Length 51.4 mm.; height 29 mm. View of the exterior of a right valve. P. 333

Fig. 10. *Dermatomya tenuiconcha* Dall. View of the interior of the specimen shown in fig. 6.

Fig. 11. *Dermatomya tenuiconcha* Dall. View of the interior of the specimen shown in fig. 7.

Fig. 12. *Panomya* cf. *P. beringiana* Dall. Hypotype (California Academy of Sciences), from Loc. 1418 (CAS), northeast corner of India and Spruce streets, San Diego. Length 44 mm.; height 38 mm. View of the exterior of a cast of a left valve. P. 329

Fig. 13. *Dermatomya tenuiconcha* Dall. Enlarged view of the hinge area of the specimen shown in fig. 11.

Fig. 14. *Tellina (Moerella) carpenteri* Dall. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM), at the same elevation. Length 14.6 mm.; height 9.9 mm. View of the exterior of a left valve. P. 288

Fig. 15. *Hiatella arctica* Linnaeus. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 14. Length 5.6 mm.; height 1.3 mm. View of the exterior of a juvenile left valve. P. 326

Fig. 16. *Penitella penita* Conrad. View of the interior of the specimen shown in fig. 9.

Fig. 17. *Hiatella arctica* Linnaeus. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 14. Length 6.3 mm.; height 2.8 mm. View of the interior of a left valve. P. 326

Fig. 18. *Hiatella arctica* Linnaeus. View of the exterior of the specimen shown in fig. 17.

Fig. 19. *Panope generosa* Gould. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 14. Length 106 mm.; height 72 mm. View of the dorsal area. P. 328

Fig. 20. *Panope generosa* Gould. View of the exterior of the right valve of the specimen shown in fig. 19.

Fig. 21. *Sphenia* cf. *S. luticola* Valenciennes. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 6. Length 3.8 mm.; height 2.7 mm. View of the exterior of a left valve. P. 321

Fig. 22. *Sphenia* cf. *S. luticola* Valenciennes. View of the interior of the specimen shown in fig. 21.

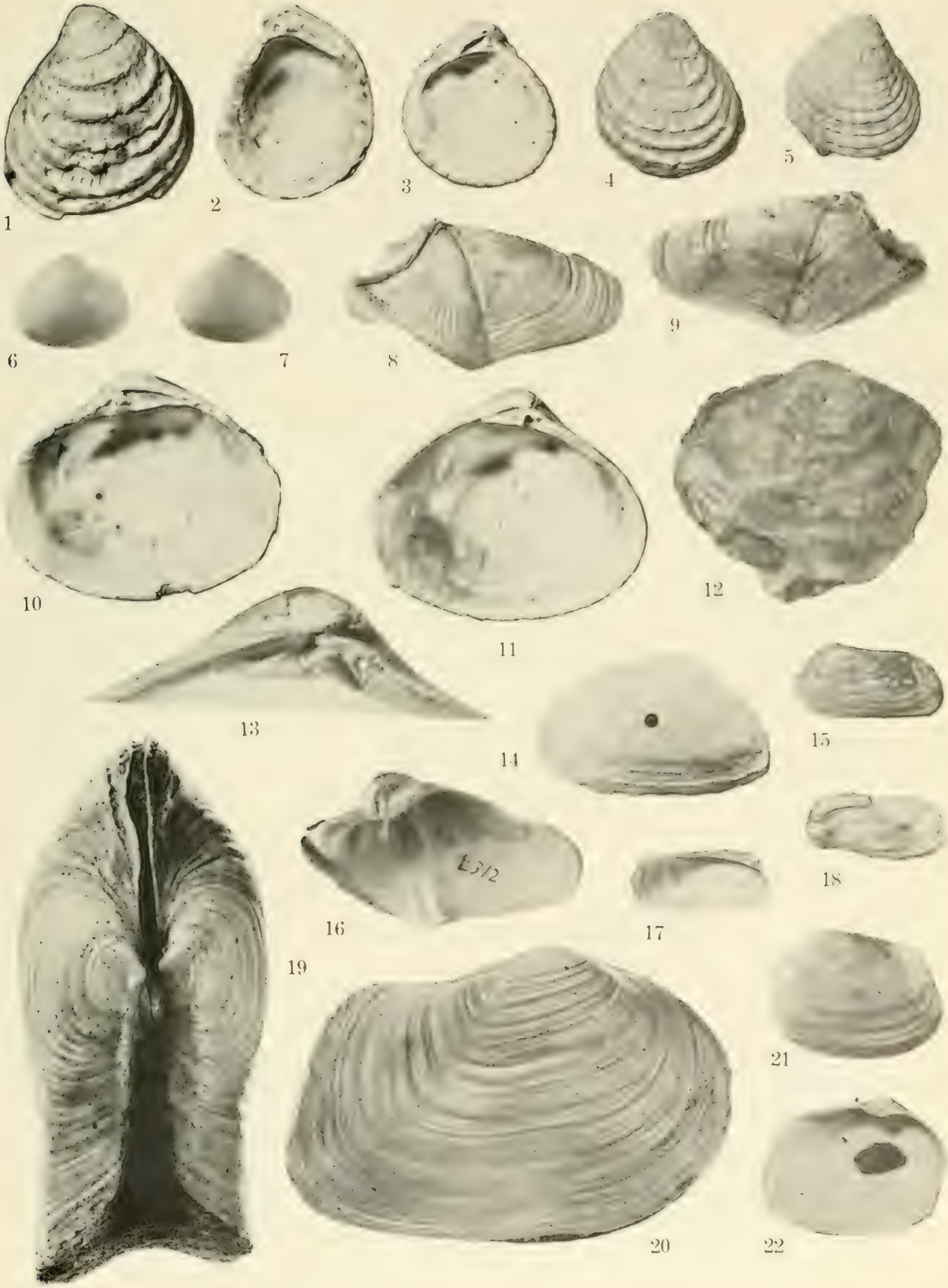
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PLATE 57

Fig. 1. *Penitella penita* Conrad. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego. Length 47.2 mm.; height 30.4 mm. Dorsal view. P. 333

Fig. 2. *Penitella penita* Conrad. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 1. Length 44.4 mm.; height 25.9 mm. View of the exterior of a right valve. P. 333

Fig. 3. *Corbula gibbiformis* Grant and Gale. Hypotype (University of California at Los Angeles), from Loc. 2359 (UCLA), in small canyon parallel to and about 0.2 mile west of the mouth of Rose Canyon and 0.4 mile north of Garnet Avenue, La Jolla quad., San Diego. Length 14.9 mm.; height 14.6 mm. View of the interior of a right valve. P. 323

Fig. 4. *Corbula gibbiformis* Grant and Gale. View of the exterior of the specimen shown in fig. 3.

Fig. 5. *Penitella conradi* Valenciennes. Hypotype (Los Angeles County Museum), from Loc. 305C (LAM), exposure at base of hill, 100 feet west and 440 feet south of the northeast corner of Sec. 8, T. 19 S., R 2 W., San Bernardino Base and Meridian (see U.S. Geol. Survey topog. map, San Ysidro quad., revision 1953). Length 25 mm.; height 20.3 mm. View of the exterior of the left valve. P. 332

Fig. 6. *Basterotia (Basterotella) hertleini* Durham. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 5. Length 11 mm.; height 7.3 mm. View of the interior of a right valve. P. 241

Fig. 7. *Ensis myrae* Berry. Hypotype (Los Angeles County Museum), from Loc. 305A (LAM), west side of next gully east of Loc. 305 (LAM), at the same elevation. Length (incomplete) 14 mm.; height 8.6 mm. View of the interior of the anterior end of a left valve. P. 309

Fig. 8. *Donax (Serrula) gouldii* Dall. Hypotype (Los Angeles County Museum), from Loc. 319 (LAM), exactly between the United States-Mexico boundary fence and Mr. Ericson's (the manager's) house, 27 feet above the road level on the shoulder of the second hill. Length 21.2 mm.; height 10.9 mm. View of the exterior of a left valve. P. 303

Fig. 9. *Diplodonta (Diplodonta) orbella* Gould. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian, southwestern San Diego Co. Length (approximately) 18 mm.; height 17 mm. View of the exterior of a right valve, the posterior margin incomplete. P. 252

Fig. 10. *Lima (Limaria) orcutti* Hertlein and Grant. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 5. Length 35.8 mm.; height 44.8 mm. View of the exterior of a right valve. P. 215

Fig. 11. *Basterotia (Basterotella) hertleini* Durham. View of the exterior of the specimen shown in fig. 6.

Fig. 12. *Spisula (Mactromeris)* cf. *M. (M.) planulata* Conrad. Hypotype (University of California at Los Angeles), from Loc. 294 (UCLA), 200 feet north of Mexican boundary and ¾ mile east of the coast, exposure in east-west ravine tributary to a larger south-north ravine at right angle, in first terrace above Tiajuana river plain. Length 31.7 mm.; height 25.3 mm. View of the exterior of a right valve.

Fig. 13. *Penitella conradi* Valenciennes. Dorsal view of the specimen shown in fig. 5. P. 332

Fig. 14. *Cuspidaria (Cardiomya) pectinata* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 7 mm.; height 4.2 mm. View of the exterior of a right valve. P. 342

Fig. 15. *Compsomyax subdiaphana* Carpenter. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 9. Length 32.7 mm.; height 26.4 mm. View of the exterior of a right valve, umbonal portion incomplete. P. 269

Fig. 16. *Spisula (Mactromeris) hemphillii* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 9. View of a portion of a right valve 54 mm. long, showing the hinge. P. 315

Fig. 17. *Nuculana* aff. *N. leonina* Dall. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 9. Length 8.6 mm.; height 4.8 mm. View of the interior of a right valve. P. 149

Fig. 18. *Diplodonta (Diplodonta) orbella* Gould. View of the interior of the specimen shown in fig. 9.

Fig. 19. *Ensis myrae* Berry. Hypotype (Los Angeles County Museum), from the same locality as the specimen shown in fig. 7. Length 65.8 mm.; height 10.4 mm. View of the exterior of a right valve embedded in sediment in the interior of a left valve of *Spisula hemphillii* Dall. P. 309

Fig. 20. *Nuculana* aff. *N. leonina* Dall. View of the exterior of the shell shown in fig. 17.

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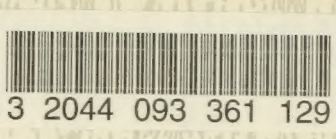
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